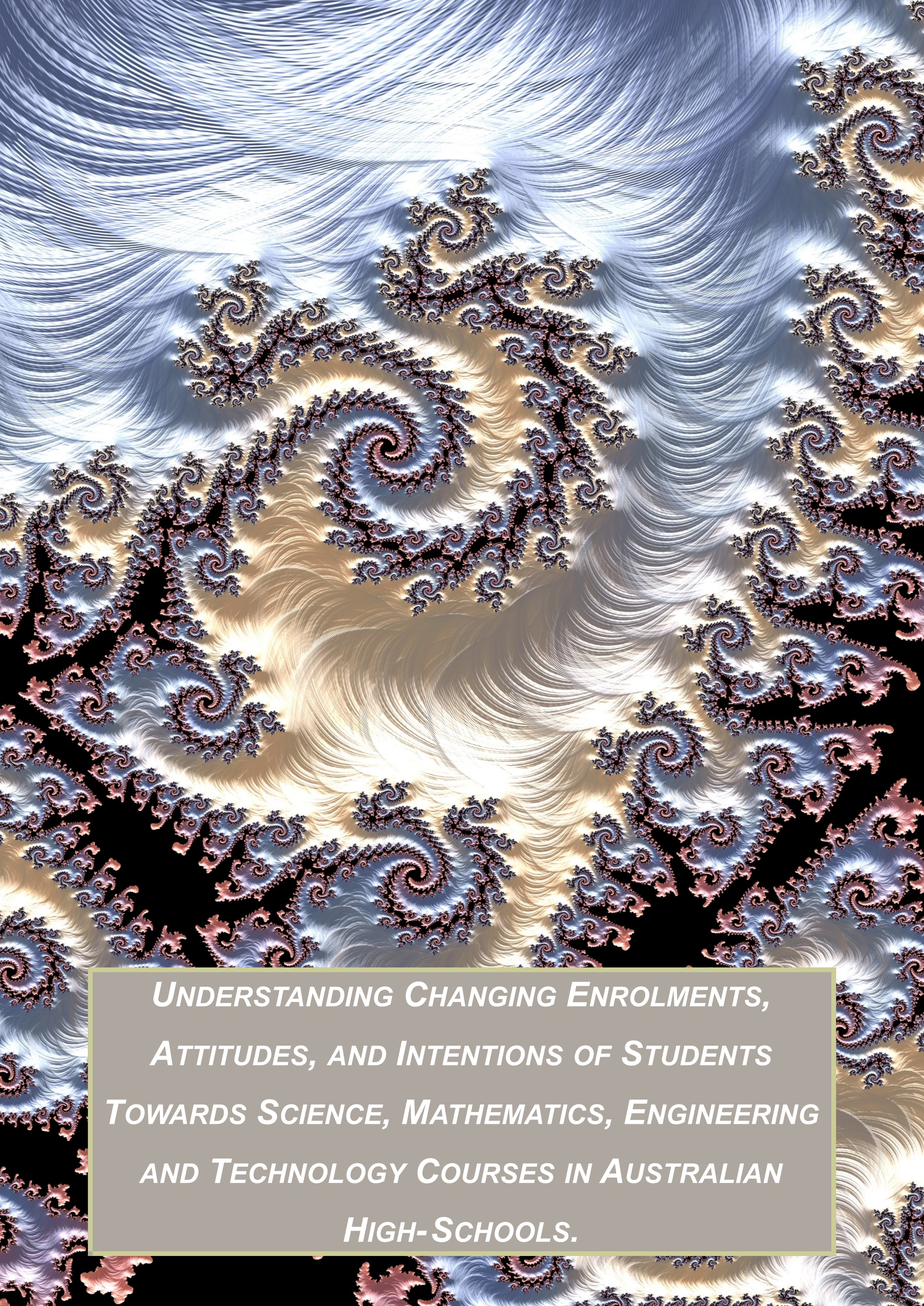

Understanding Changing Enrolments, Attitudes, and Intentions of Students Towards Science, Mathematics, Engineering and Technology Courses in Australian High-Schools.

UNDERSTANDING CHANGING ENROLMENTS, ATTITUDES, AND INTENTIONS OF STUDENTS TOWARDS SCIENCE, MATHEMATICS, ENGINEERING AND TECHNOLOGY COURSES IN AUSTRALIAN HIGH-SCHOOLS.

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A thesis submitted for the degree of

DOCTOR OF PHILOSOPHY,

University of New England.

September 2018

Declaration of Originality

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis and all sources used have been acknowledged in this thesis

[redacted]

JohnPaul Kennedy

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AN INTELLIGENT MIND ACQUIRES
KNOWLEDGE,
AND THE EAR OF THE WISE SEEKS
KNOWLEDGE.

- PROVERBS 18:15

EDUCATION IS THE MOST POWERFUL
WEAPON WHICH YOU CAN USE TO
CHANGE THE WORLD.

- NELSON MANDELA

To Grace, Evangeline, Solomon and Noah

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Over the lifespan of this research project, many, many people have provided motivation, encouragement, and support in ways beyond imagination as well as heartfelt, and sometimes critical, advice that has enabled me to reach this point.

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In a similar vein, I wish to thank my three examiners for their gracious comments and thoughtful recommendations that have improved this final thesis as a whole.

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Ethics

This study has been completed under the following human research ethics approvals. All data collection and analyses were carried out in accordance with these protocols and all conditions of these approvals have been complied with.

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Abstract

This thesis investigates the interplay between students' attitudes towards the science, technology, engineering and mathematics learning areas—the STEM subjects—as taught in Australian high-schools and their intentions to enrol in these subject areas in post-compulsory education. Falling enrolment rates in these areas have attracted much attention in recent years and there have been numerous strategies implemented in an attempt to reduce the declines. A common approach to addressing the problem of declining participation has been to devise strategies that target students' attitudes towards the STEM subjects with the implication that positive attitudes increase the likelihood of continued student enrolments. Research findings have provided different insights into students' intentions or enrolments, though there has been little conclusive evidence of an association between intentions and enrolments.

Given the lack of clarity surrounding some of these issues apparent in the research corpus, this thesis takes a novel approach to address a number of methodological impediments to further progress in this field. In studying changes in students' attitudes towards individual STEM subjects this study also considered students' changes in attitudes towards the academic aspects of school more generally. This approach enables a measure of student attitudes to school subjects overall, to be used as a point of reference against which to assess attitudes specifically in relation to the STEM subjects. Further, while the majority of attitude studies have been cross-sectional—either surveying a single age cohort at a point in time, or surveying different age cohorts and drawing conclusions about differences—this thesis adopted a longitudinal approach to the research design. Finally, in contrast to common media rhetoric, enrolment trends and attitudinal patterns across the wide range of STEM subject areas were investigated and were not limited to just science and mathematics.

This thesis explores the nexus between enrolments and attitudes through the format of two introductory chapters, four published and one unpublished journal articles, and a general discussion combining the conclusions of each article with each other and with the existing literature.

The first two papers illustrate how patterns of student participation in the STEM subject areas in Australian high-schools have changed since 1992 onward. The data were

then interrogated in search of common enrolment themes and correlations. It was found that the enrolment patterns and the scale of the changes in them were noticeably different for each of the STEM subjects indicating that they were each subject to separate underlying influences.

The third paper presents the development, validation and use of the School Science Attitude Survey (SSAS). This digital survey instrument captures students' self-measures of attitudes towards school subjects, across seven attitudinal constructs and enables changes in those attitudes to be investigated using Attitude Profiles and Attitude trajectories. The fourth and fifth papers make use of the SSAS data to investigate changes in attitudes for Year 7 students across science, mathematics and technologies, and to analyse differences in attitude trajectories for students in science as they proceed through Year 7 and 8.

The SSAS also obtained qualitative data around changes to student attitudes that were analysed though the use of network maps. These revealed that among many explanatory factors offered by students, there were a small number of key explanations that were particularly central to the formation and refinement of attitudes towards STEM areas.

Following this approach, this thesis shows that while participation rates in some STEM subject areas continue to decline, albeit slowly, other areas are either stable or experiencing mild growth. It is also shown that students' enrolment intentions towards STEM subjects are strongly interrelated with the nature of the attitudes that students hold for those subjects.

Chapter 7

A longitudinal analysis of student attitudes of enjoyability and relevance towards school science across the first two years of Australian high-school

Contents

Appendices

Index of Tables

Index of Figures

List of Abbreviations

ABS...........Australian Bureau of Statistics
AC.............Attitude Construct
ACARA….Australian Curriculum, Assessment and Reporting Authority
ACER........Australian Council for Educational Research
ACT..........Australian Capital Territory
AT.............Attitude Trajectory
ATAR........Australian Tertiary Admissions Rank
CAP...........Composite Attitude Profile
CAR..........Composite Attitude Rating
COAG.......Council of Australian Governments
IBDP.........International Baccalaureate Diploma Programme
IBO...........International Baccalaureate Organisation
KLA..........Key Learning Area
LSAY........Longitudinal Surveys of Australian Youth
LT.............Likert-type
NCVER.....National Centre for Vocational Education Research
NSW..........New South Wales
OECD........Organisation for Economic Cooperation and Development
PCSC......... Perceived Challenge and academic Self-Concept scale
PISA..........Programme for International Student Achievement
RAP...........Results Analysis Package
ROSE........Relevance of Science Education (project)
RQ............Research Question
RT.............Research Theme
SAP...........Subject Attitude Profile
SAR...........Subject Attitude Rating
SD............Semantic Differential
SPLOM.....Scatterplot Matrix
SSAS.........School Science Attitude Survey
STEM........Science, Technology, Engineering and Mathematics
TOSRA.....Test of Science Related Attitudes
UAC..........Universities Admissions Centre
VAS...........Visual Analogue Scale
VASS.........Views About Sciences Survey
VET...........Vocational Education and Training
VIC...........Victoria
VSS...........Very Simple Structure

UNDERSTANDING CHANGING ENROLMENTS, ATTITUDES, AND INTENTIONS OF STUDENTS TOWARDS SCIENCE, MATHEMATICS, ENGINEERING AND TECHNOLOGY COURSES IN AUSTRALIAN HIGH SCHOOLS.

Chapter 1: Introduction

1.1 Rationale

Year 12 participation rates in science and mathematics courses in Australian secondary schools have been in decline for many years. Reports by a number of research teams (e.g., Ainley, Kos, & Nicholas, 2008; Dekkers & de Laeter, 2001; Dekkers & Malone, 2000; Forgasz, 2006; Barrington, 2006; Khoo & Ainley, 2005; Fullarton, Walker, Ainley, & Hillman, 2003) showed clearly that the percentage of students studying the higher levels of mathematics and the enabling sciences fell quite dramatically throughout the 1990s but suggested that they may have been beginning to stabilise in the early 2000s. Furthermore, the trends and patterns described are not restricted to just the Australian education system: Garg and Gupta (2003) in India, Smith (2011) in the UK, and Trumper (2006) in Israel—among many more—serve as examples where similar issues have been identified.

At the outset of this study, there was a flurry of media and other coverage (e.g., O'Keeffe, 2012; D. Smith, 2011; Thompson, 2011) surrounding the release of reports into Year 12 student choices in Australia (e.g., Goodrum, Druhan, & Abbs, 2011; Universities Australia, 2012). The ensuing discussions brought to the fore the importance and value of science and mathematics in our society in terms of Australia's knowledge economy, and ignited the public debate around why students should choose to study Science, Technology, Engineering and Mathematics (STEM[1]) subjects in upper high-school. However, these enrolment data for Australian schools were beginning to lose relevance due to their age and no central agency was compiling or releasing these data at the national level. It was therefore a priority to collect, analyse and publish these data for the STEM-related fields so that up to date information was available to inform research in this topical and important area.

Ultimately the choice whether or not to study STEM subjects at school and beyond forms a series of parallel, yet interconnected, pathways as shown in Figure 1.1. This figure demonstrates that students can follow multiple pathways through upper secondary school,

1 The acronym STEM has been used variously in educational contexts to mean both an integrated approach to learning scientific, mathematical and technological skills and ideas—either as a single school subject or through an interdisciplinary approach to learning—and as shorthand term for the four separate disciplines of science, mathematics, technologies and engineering. Throughout this thesis, the term STEM is utilised with this latter definition as this reflects the predominant approach to teaching and learning currently implemented for these school subjects within the Australian education system.

studying various mathematics and science courses and carry on to various tertiary studies. It also shows how students can leave the formal education system at multiple points in the process. From the perspective of future careers in STEM and STEM-related fields, the choices made by individual students at different points in time have resulted in particpation trends that some commentators have described as a “leaky pipeline” (Clark Blickenstaff, 2005; Lips & McNeill, 2009; Varma & Hahn, 2008; Watt, Eccles, & Durik, 2006). The prevailing message in much recent literature has been that school-based STEM is, to an extent, for everyone and therefore it is imperative that these leaks be *plugged* (Carnevale, Smith, & Melton, 2011; Tytler, Osborne, Williams, Tytler, & Cripps Clark, 2008; Zollman, 2012). In 2016 over 600 different initiatives were in place across Australia to attempt to engage students in various aspects of STEM education (Office of the Chief Scientist, 2016), while a Google Scholar search using the terms “STEM” AND “attitudes” AND “school” retrieved over 34000 articles published in 2016 and 2017 alone. However, even given all this attention and focus, STEM subjects have remained a concern on many fronts and there seems to be little consensus as to the underlying causes of the declines in participation nor the most suitable solutions to the issues.

A range of anecdotal evidence, professional concerns and personal convictions provided the impetus for this study. Personal observation gave the impression that, for physics and advanced mathematics at least, the long term declines in enrolments continued throughout the first decade of the twenty-first century. This seems counter-intuitive especially when considering the ever increasing technological nature of Australian society—that is to say, more and more technologically complex devices are pervading everyday life, yet fewer senior high-school students appear to be electing to study the STEM subjects at the highest level. At first glance, we seem, as 'digital citizens', to have less desire to understand *why* things work and simply accept that they *do*. In my experience the STEM subjects at school comprise not just as a body of knowledge that needs to be passed on, but a collection of logical methods and techniques that can be applied to many problems in the world. They have also traditionally formed the bedrock for further tertiary study in the natural sciences and engineering. It is these missed opportunities for training in STEM-related problem solving, complex analysis, and critical thinking, which greater numbers of students have been choosing not to experience, which I find most concerning for the future and which formed part of the impetus for this study.

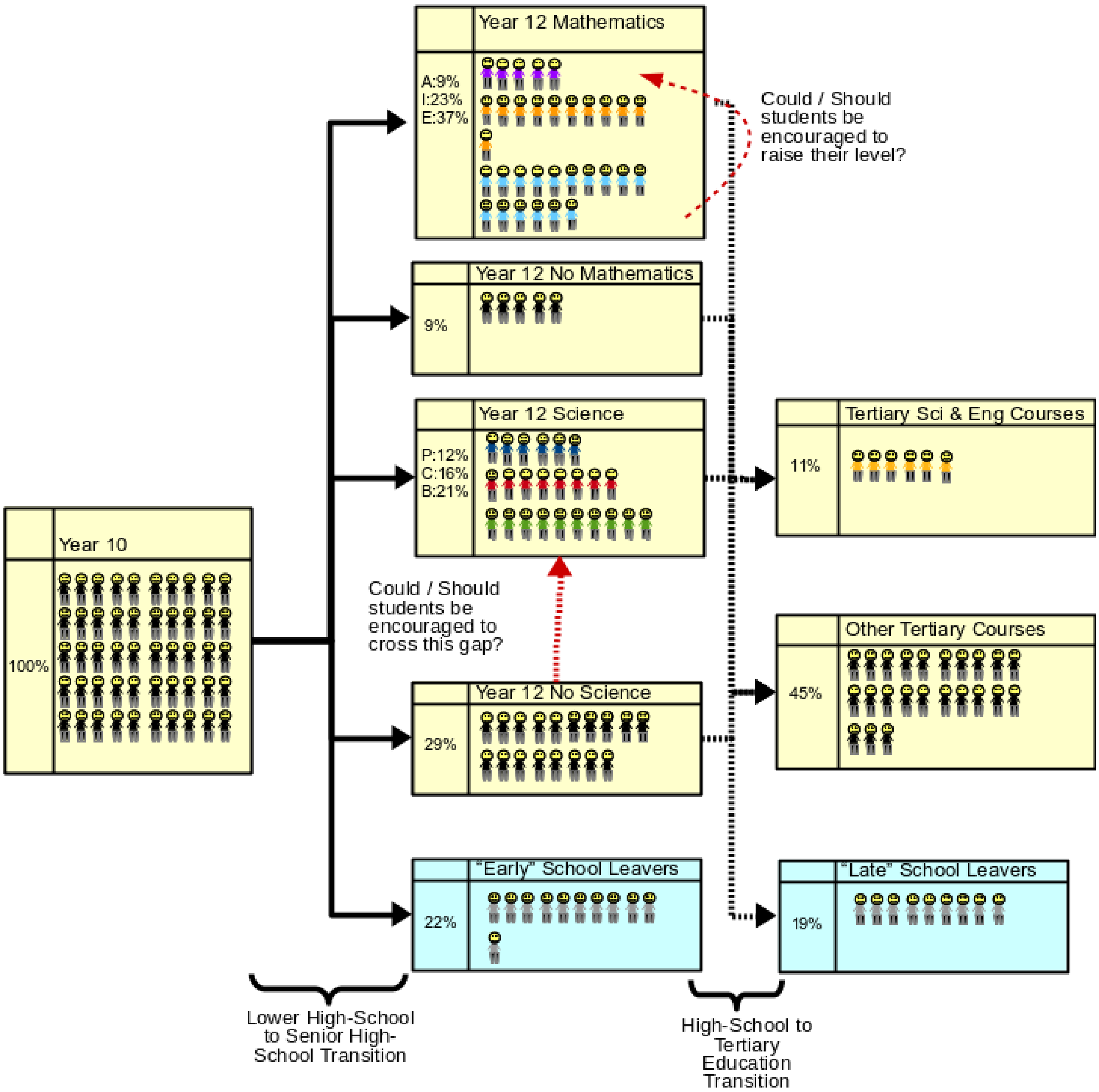

Figure 1.1. Student pathways in science and mathematics from Year 10 through to tertiary study. Numbers based on (Kennedy, Lyons, & Quinn, 2014) and (Graduate Careers Australia, 2010).

Early school leavers refers to students who leave formal education prior to Year 12. Late school leavers refers to students who complete Year 12 but do not go on to further tertiary education. At year 12 level, various science and mathematics courses are offered. Typically these include physics (P), chemistry (C) and biology (B), advanced mathematics (A), intermediate mathematics (I) and entry mathematics (E).

1.2 General Research Themes

This study aims to understand the current high-school enrolment trends in the various STEM disciplines and the attitudes of students towards science and mathematics courses in particular. Moreover, it aims to describe some of the possible influences on student attitudes and hence understand some of the changing patterns in student enrolment intentions towards post-compulsory STEM-related courses of study (see Figure 1.1).

In addressing these aims, this study will investigate the following two general research themes:

RT1 What are the present enrolment trends in post-compulsory STEM disciplines in Australian high-schools?

RT2 How do student attitudes towards STEM-related courses change over time in comparison with other school subjects?

1.3 Project Scope and Boundaries

In order to address these research themes, enrolment data will need to be collected from across Australia over a sufficiently long period of time so as to enable connection and comparison of any findings with those of previous researchers (Ainley et al., 2008; Barrington, 2006; Dekkers & de Laeter, 2001). In addition, the concept of student attitudes (discussed in more detail in Chapter 2) is rather broad and thus only those attitudinal influences identified by the existing literature as having a significant effect on student choices will be investigated in this study. The following criteria will therefore be considered to be the boundaries of the study:

- Only enrolment trends within Australian mainstream high-schools will be considered. Unusual cases such as students in international schools following Australian courses are considered to be beyond the scope of this project.
- The project is primarily concerned with the enrolment trends on a national level. The specific trends within individual states, schools or education systems are beyond the realm of the project.
- The project is concerned with understanding how students' attitudes towards their school subjects correlate with their future enrolment intentions in that subject area.

External, uncontrollable influences that cannot be expected to directly impact these student attitudes are considered beyond the scope of this study.

1.4 General Methodology

This project adopts a post-positivist paradigm (Guba & Lincoln, 1994) which can be summarised as a critical view of a probabilistic reality in which hypotheses are falsifiable and based on a mostly objectivist epistemology. That is to say that reality can be investigated using quantitative and qualitative methodologies which will lead to conclusions that can be considered to be likely to be true.

Post-positivism is an appropriate paradigm for a study of this nature as the project is fundamentally concerned with questions about statistical trends in a nationwide set of quantitative data and the underlying descriptions of attitudes that may account for any changes observed on the coarse scale. Furthermore, I consider that this approach to measuring observable phenomena at the statistically large scale, without necessarily focussing in detail on individual cases, can yield important insights into documenting and understanding change at a system-wide level that can not be attained through other approaches, and can complement more narrowly-focussed, contextually-situated qualitative studies. While an interpretivist approach may be better suited to yielding explanations at the individual or small groups scale than my post-positivist approach, I feel that any attempt to generalise those explanations beyond this local scale would prove to be unworkable. In contrast, while my adopted approach lacks some of the explanatory power of interpretivism, I feel that my approach will be more effective in describing and explaining trends and patterns at the large scale.

In order to gain an understanding of the research themes I have adopted a mixed methodology utilising both quantitative and qualitative methods. While the specific details and rationales behind the methods adopted are outlined in each of the following chapters, this study has:

- collected, collated and analysed large scale data on nationwide enrolments in the STEM disciplines together with 26 other course areas for the purposes of comparison.

- developed and validated a digital, attitudinal survey instrument that can be administered on mobile devices as well as traditional computers to capture student attitudes towards both STEM subjects and school courses in general.
- adopted techniques for cross-sectional and longitudinal analysis of the large-scale attitudinal dataset captured by the instrument described above so as to describe the effects of individual attitudes and combinations of attitudes on students' enrolment intentions for upper high-school.
- captured and examined qualitative explanations offered by students that provide insight into the causes and extent of their changing attitudes towards the various school STEM disciplines.

1.5 Thesis Structure

This thesis is submitted in the form of a collection of articles in journal article format, which is one of the thesis structures supported by the university's higher degree by research procedures. Each of the chapters corresponding to a published article follows the same structure: firstly, an introduction that places the chapter in the larger context of the thesis and then a reference to the published article and any relevant impact information. This is followed by the article reformatted for the purposes of the thesis and then a statement of authors' contributions. The analyses and articles contained in this thesis are the result of a research process that began in November 2010 and continued (part-time) over the subsequent seven and a half years and deal with research having common conceptual, methodological and literature threads throughout. Therefore, it is inevitable that the articles that comprise this thesis—which are not presented in chronological order—reflect these commonalities and consequently there are some significant areas of overlap and apparent repetition between chapters. This may be particularly true in regards to the article introductions and discussions.

Each of the following chapters contributes to the overall knowledge and understanding of this thesis by addressing the general research themes outlined previously (Section 1.2) and the detailed research questions (Section 2.2) that emerge from the existing literature. The published articles that comprise Chapters 3 to 7 also have a number of focussed research questions that allow the reader to understand the research presented in each article without reference to the this thesis as a whole. The relationship between

Research Themes, Detailed Research Questions and Focussed Research Questions is shown in Table 1.1.

Chapter 2 provides a succinct overview of the literature in this field as it existed at the outset of this study. Given the volume and intensity of research output in this field over the duration of the project, it is important to understand where this study fits into the wider field in the context of the time. The approaches and models towards understanding student attitudes and enrolment trends extant at the outset of the study are briefly discussed and critiqued and the areas of research concern and need are identified. Detailed research questions to be addressed by the thesis as a whole are then outlined. Informed by the literature, a theoretical framework is developed through which all other aspects of the study are grounded. A brief update of the relevant literature, as it has changed over the intervening seven years, is then provided at the end of the chapter. Although not published, this chapter is presented in the same journal article format as the subsequent chapters.

Chapters 3 and 4 present two articles that describe the enrolment trends for the past two decades in science and mathematics (Chapter 3), and in technologies and engineering (Chapter 4). These articles provide much of the background information to the nature and extent of the *crises* in enrolments on which the majority of the more recent media and popular science rhetoric has been focussed. These analyses are based on raw enrolment data that were collected and compiled from across Australia and that is presented in Appendix A.

Chapter 5 details the development, trial, and refinement of the digital collection instrument utilised to obtain the data analysed in the following chapters. The original appendices to this article are presented in Appendix C of this thesis.

Chapters 6 and 7 examine student attitudes towards STEM subjects over the first years of high-school, using data captured by the instrument described in Chapter 5. Chapter 6 provides a high level overview analysis of students' attitudes towards school science, mathematics and technology and focuses on comparing Attitudinal Profiles at a number of points in Years 7 and 8. Chapter 7 is a more focussed discussion centring around the key attitudes of students towards school science. In particular, longitudinal trends of students' attitude trajectories are analysed and discussed in confluence with qualitative explanatory data collected directly from the students.

Chapter 8 examines the patterns, similarities and incongruities between the research articles as a whole and draws conclusions with respect to the general research questions identified above and developed in Chapter 2. Implications for practice, theory and further research are also considered.

A short article, originally presented in the form of a research poster, that reflects on the implications of the declining trends in science and mathematics for the context of a co-educational, independent, K-12 school in New South Wales is presented in Appendix B.

Table 1.1: The relationships between Research Themes (RT), Research Questions (RQ), and focussed research questions in the published articles of this thesis.

Chapter	Focussed Research Questions	RT1					RT2		
		RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7	RQ8
3	• How has the participation of Australian Year 12 students in science and mathematics courses changed between 1992 and 2012? • What is the effect of student sex on student participation in Australian Year 12 science and mathematics courses? • What factors appear to impact student participation rates in Australian Year 12 science and mathematics courses?	✔			✔	✔			
4	• What are the current and historic patterns of enrolment in Australian Year 12 technologies courses? • What is the effect of student sex on student participation in Australian Year 12 technologies courses? • What factors appear to impact student participation rates in Australian Year 12 technologies courses? • To what extent are the enrolment patterns in Australian Year 12 technologies courses similar and/or different to the enrolment patterns in science and mathematics courses?		✔	✔	✔	✔			
5	• Can a single, web-based instrument be developed to measure multiple facets of a student's attitude towards school science? • Can student attitudes towards school science be reliably measured in a time-efficient manner using single-item measures?						✔		

Chapter	Focussed Research Questions	RT1					RT2		
		RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7	RQ8
6	• How do students' attitudes towards STEM subjects compare to their attitudes to school in general as they begin high-school? • Are there any differences in the attitude profiles of male and female students? • Which attitudinal constructs have the strongest association with a student's intention to continue with a STEM-focussed education? • How fixed are students' attitudes towards STEM subjects over the first year of high-school?						✔	✔	
7	• How do students' attitudes of enjoyability and relevance of school science change as they progress through Year 7 and Year 8 of high-school? • What is the nature of any relationship between enjoyability, relevance and intention to enrol in science subjects in post-compulsory education for students in Year 7 and 8? • Do student and school-based factors, such as student sex and school location, impact the enjoyability and relevance of school science through Years 7 and 8? • What explanations do students offer for their changing attitudes of enjoyability and relevance in relation to school science through Years 7 and 8?							✔	✔

1.6 Significance and Originality

The significance of the problem of STEM enrolments that is the focus of this thesis became even more apparent over the course of this research. During the period, the public discussion regarding STEM in schools has resulted in a number of reports being published that have highlighted the discipline significance for students studying science and mathematics (Holmegaard, Madsen, & Ulriksen, 2014; Lederman & Lederman, 2013), the economic importance of STEM (Deloitte Access Economics, 2014; Prinsley & Baranyai, 2015), the relevance of student attitudes and motivations towards STEM (Potvin & Hasni, 2014; Universities Australia, 2012), and the significance of STEM for female students (Sadler, Sonnert, Hazari, & Tai, 2012; Zagami, Boden, Keane, Moreton, & Schulz, 2015).

Of particular interest has been a series of publications by the Australian government through the Office of the Chief Scientist (Commonwealth of Australia, 2015; Office of the Chief Scientist, 2013; Prinsley & Baranyai, 2015) which highlighted the necessity of halting the declines in STEM subject enrolments and resulted in the publication of a National School STEM Education Strategy (Education Council, 2015). These reports have influenced, both directly and indirectly, the direction and foci of this study. In addition, the political aims and foci of successive governments, at both the federal and state level across Australia, have at different times shone particular emphases on the social importance and educational imperatives of different aspects of this study.

This study is therefore timely as it provides much-needed empirical data about current enrolment trends in the STEM disciplines across Australia, which can serve as a solid evidence base to underpin wider discussions in this field. It brings this knowledge up to date, building upon the previous findings of Dekkers and de Laeter (2001) and Ainley, Kos and Nicholas (2008). Due to its salience to current social and research priorities, the data collected through this study, and the corresponding analyses, have been influential in informing the STEM debate in Australia. They have been drawn on and cited by several other researchers in the field (e.g., Aubusson, Panizzon, & Corrigan, 2016; Blackley & Howell, 2015; Hackling, 2014; Lyons & Quinn, 2015; G. N. Masters, 2016), have been referred to in numerous media reports (Phillips, 2014; ‘The enchanting wonder’, 2014) and have also been utilised in developing government position papers (Lowe, 2014; Office of the Chief Scientist, 2013, 2014).

The longitudinal study undertaken as part of this research has mapped students' attitudes towards STEM subjects over the years of high-school. The resulting innovative attitudinal measurement instrument (Kennedy, Quinn, & Taylor, 2016), that merged traditional measurement tools with modern technology, has been replicated and developed further by other researchers (Blackweir, 2016; Toma & Meneses Villagrá, 2018) and has been shown to be robust.

This study is original because it not only describes the changing enrolment trends of Australian high-school students but also identifies, through the use of attitudinal profiles some of the influences affecting students’ intentions to enrol in these subjects. This appears to be an unique approach in explaining the observed STEM enrolment trends. The longitudinal study has tracked students over periods of up to four years—in some cases tracking students throughout their entire compulsory high-school life—and utilises a new technique to obtain data on student attitudes towards school. This yields a new way of looking at student enrolment intentions that has the potential to influence the future methods and approaches researchers take in this field.

Chapter 2: Understanding the changes in post-compulsory science enrolments in Australian high-schools: a summary of the literature.

2.1 Introduction

This chapter provides an overview of the existing literature in the area of STEM enrolment trends, attitudes towards science, and the explanatory models used to describe the changes in student participation extant at the outset of this research in 2011. In particular, this chapter examines the ground breaking work of Dekkers, de Laeter and Malone (Dekkers & de Laeter, 2001; Dekkers & Malone, 2000) in regards to enrolment patterns and Gardner (1975) and Ormerod and Duckworth (1975) in regards to attitudes towards science. The chapter then considers the numerous studies that extended and developed their research including some of the key studies that have been published during the progress of this study.

The purpose of this chapter is not to examine the existing body of literature in minute detail but to identify the knowledge gaps that existed at the outset of this research study. As the chapters that follow have the form of independent journal articles, each one has its own, more focussed, literature review. The general overview provided by this chapter allows the the two research themes from Chapter 1 to be developed into a series of specific research questions for further investigation in this thesis. Additionally, this chapter outlines the theoretical framework that guides the interpretation and understanding of the subsequent articles as well as the study as a whole.

2.2 General Literature Review

Although written in Journal Article format, this chapter has not been submitted for publication in any journal. It is heavily influenced by the report submitted in fulfilment of the requirements for the Confirmation of Candidature process at the university and the feedback received at that time.

Understanding the changes in post-compulsory science enrolments in Australian high-schools: a summary of the literature.

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For many years there have been reports of declining participation in post-compulsory school science, mathematics and technologies courses across Australia. Similarly, many researchers have also identified declining attitudes towards science and mathematics by school students and suggested that attitudes and enrolments are intertwined. There have been many varied attempts to understand these historical declines in terms of complex reasoning processes or in terms of interactions with background and/or demographic factors, and a great many programs have been implemented to try to reverse them, to differing degrees of success. This article offers an historic summary of the literature relevant to understanding the nature and state of these STEM enrolments declines as it existed at the outset of this research study in 2011. From this body of research, a theoretical framework is developed to better aid in understanding the changing patterns in STEM enrolments within the context of attitudes being utilised by students in a reasoned action decision process. A brief update of relevant literature as it developed over the seven years of this study is then provided so as to ground the research themes (and overall findings) of this study in the research contexts of the present time. Finally, detailed research questions for further investigation are then identified.

Introduction

For many years there have been reports of declining participation in post-compulsory school science, mathematics and technologies courses across Australia (e.g., Ainley, Kos, & Nicholas, 2008; Dekkers & de Laeter, 2001; Dekkers & Malone, 2000). International studies have shown that these declines have not been confined to Australia with various researchers attempting to understand these changes (e.g., Clark Blickenstaff, 2005; Eccles & Wigfield, 2002; Fullarton, Walker, Ainley, & Hillman, 2003; Lyons, 2006; Lyons & Quinn, 2010; Morrell & Lederman, 1998; Osborne, Simon, & Collins, 2003; Osborne, Simon, & Tytler, 2009; Simon & Osborne, 2010; E. Smith, 2011; Speering & Rennie, 1996; Wigfield & Eccles, 2000). Australia has seen many programs implemented to try to reverse the falling participation in STEM areas (Office of the Chief Scientist, 2016). A common assumption among the explanations has been the implicit link between students' attitudes towards school STEM disciplines and their enrolment decisions in these areas. Often it is suggested that the less than favourable attitudes held by students towards science, results in more negative enrolment intentions towards science courses in upper high-school and by extension into future careers (e.g., Bennett, Braund, & Sharpe, 2013; Khoo & Ainley, 2005; Norwich & Jaeger, 1989).

This article offers a historic summary of the literature relevant to understanding the nature and state of these declines prior to the outset of this study in 2011. Given that numerous researchers have suggested a correlation between enrolments and attitudes, a brief synopsis of the research relevant to understanding and measuring students attitudes towards the STEM areas then follows. From these two areas of research, a theoretical framework is developed to aid in better understanding these patterns of enrolments and the links to student attitudes towards school subjects. Detailed research questions for further investigation are then identified.

Australian STEM Enrolment Trends 1970 to 2010

Many researchers have examined the enrolment trends of high-school sciences over the forty year period prior to 2010, both in Australia (Ainley et al., 2008; Dekkers & de Laeter, 2001; Dekkers, De Laeter, & Malone, 1986; Goodrum, Druhan, & Abbs, 2011; Lyons, 2006; Lyons & Quinn, 2010) and worldwide (Garg & Gutpa, 2003- India; E. Smith, 2011- England; Trumper, 2006- Israel). These researchers found, almost unanimously, that for much of the period from the early 1990s onwards, enrolments in post-compulsory science courses generally declined in many jurisdictions around the world.

Dekkers, de Laeter and Malone (1986) showed that from 1970 until 1985 the total Australian school population in Year 12 increased dramatically, with the number of males in Year 12 increasing by 46% over the period and the number of females doubling. This appeared to be due to increased retention of students to Year 12 rather than a surge in the overall school population. They attributed the changes in the Year 12 cohort to three main factors: firstly increased unemployment encouraged students to remain in school; secondly changing attitudes in society towards females caused more females to remain in school; and finally more job opportunities for females in previously male-dominated roles.

These overall changes are very important when taking into account the changes in the individual STEM subjects. The authors found that although all three major science subjects grew in absolute enrolment terms throughout the period, the participation rates—

the proportion of the Year 12 cohort studying a particular course—had declined steadily with the exception of chemistry (see Chapter 3). Dekkers et al. (1986) suggested that the apparent decrease in the *proportion* of students electing to study the sciences in the senior years of high-school in Australia could be possibly explained by four main drivers:

- An increased number of subjects from which to choose.
- The perceived relative difficulty of science subjects.
- Interest and enjoyment of science as a subject.
- Career relevance of science as a school subject

In 2001 Dekkers and de Laeter published a follow up study to their earlier 1986 work. They found that the earlier increases in total Year 12 cohort numbers continued to a peak in 1992 before falling away slightly until 1996. They attributed this primarily to a significant increase in the overall retention rate after 1985 to a maximum of 77% in 1992 which subsequently declined slightly.

As all three core sciences (biology, chemistry and physics) followed similar absolute enrolment trends to the population of Year 12 as a whole, Dekkers and de Laeter suggested that the participation trends were likely being driven primarily by the size of the Year 12 cohort and hence by the retention rate. They also noted that the sex-ratio in both biology and physics remained relatively static at around 65% and 28% females respectively whilst the proportion of females studying chemistry rose from 36% to 48% over the same period.

It is interesting to see that although the sex-balance in chemistry changed quite markedly over the period studied, the overall participation trends in chemistry and physics were nevertheless remarkably similar over the time frame. Given the changing sex-ratio of the cohort as a whole over this time, this may have warranted further investigation.

Lyons and Quinn (2010) investigated each of the four possible explanations hypothesised by Dekkers and de Laeter (1986) and concluded that the apparent declines were due primarily to the broadening of subject offerings in Year 12 and the removal of many pre-requisite requirements at universities. These two changes together effected tertiary course selection dynamics and resulted in many students being encouraged to follow a broader curriculum than had been the case previously.

The Longitudinal Surveys of Australian Youth (LSAY), as carried out periodically by the Australian Council for Educational Research (ACER) and later by the National Centre for Vocational Education Research (NCVER), offer a distinctly different viewpoint on the enrolment trends in both STEM subjects and other courses in Australian schools. The approach taken by the LSAY (see Fullarton et al., 2003) utilised data collected through surveys to generate a series of snapshots of the education system for cohorts of students that were followed over time. Initial data were collected when the students were in Year 9 and supplemented annually by additional telephone data collection as the students progressed through to Year 12 and beyond. The LSAY studies collected data from approximately 14000 students in 1998 equating to approximately 5.5% of the Year 9 cohort (comparison made with Australian Bureau of Statistics data (Australian Bureau of Statistics [ABS], 2010)).

Rather than offering a continuous description of the participation in Year 12 subjects, Fullarton et al. (2003) offer a comparison of data from six cohorts collected between 1980 and 2001. Comparisons of student subject choices are made both internally against their own Year 9 cohort and externally between different survey cohorts. These comparisons offered a much richer picture of the nature of each Year 12 cohort than could be obtained from just the enrolment data.

With reference to the Year 12 cohort as a whole, Fullarton et al. (2003) reported that females had been consistently 1.1 times more likely to participate in Year 12 than males throughout the period of the studies even as overall participation rose from 35% in 1980 to 79% in 2001. They commented that the effect of sex on participation levels was therefore not as strong as the data might at first suggest, partially countering the explanations offered by earlier research (Dekkers & de Laeter, 2001).

Fullarton et al. (2003) were also able to offer insights into Year 12 participation in science and mathematics, not possible in an analysis such as that of Dekkers and de Laeter (2001). They determined the proportion of students studying one or more science subjects and showed that in 2001, 55% of Year 12 students were studying at least one science subject. Ainley et al. (2008) were also able to extract comparable data from the Organisation for Economic Cooperation and Development (OECD) Programme for International Student Achievement (PISA) surveys to partially extend these insights to 2006. They showed that the proportion of Australian Year 12 students choosing multiple science courses had decreased over time, particularly in the combination chemistry-physics. This is of particular interest because the authors noted that taking multiple sciences in Year 12 is an indication of a student's academic priorities which in turn influence further education and career pathways.

The analyses of Fullarton et al. (2003) suggested that the typical physics student was male, had parents from a high status occupational level, an Asian background and had achieved well in junior sciences. In fact, when keeping all other variables equal, prior achievement was found to be the single most significant factor in explaining a student's choice to participate in physics.

It is the level of richness captured by the large-scale survey approach of Fullarton et al. (2003) that is of particular value. However, the very size of this approach logistically precludes it from ever giving more than a snapshot of Australian schools at a particular point in time. In addition, cohort attrition and the sampling methods selected meant that it was impossible for all regions and sectors to be equally sampled throughout time.

Ainley, Kos and Nicholas (2008) extended the data analyses of Dekkers and de Laeter up to the year 2007. They found that whilst biology and chemistry both suffered small declines in terms of absolute enrolments around 2000—coinciding with major curriculum changes in NSW and Victoria—both subjects recovered to around their 1998 levels by 2007. However, in terms of participation rates, all three core sciences were shown to continue to decline following 1998 albeit at a lower rate than earlier.

Attitudes towards school science

In parallel to this research focussing on declining STEM participation a large corpus of research has developed around the study of students' attitudes towards school and towards school subjects, with multiple interpretations of what is meant by "attitudes to science". This section reviews some of this literature, prior to establishing the definition of attitude towards school sciences adopted in this thesis.

Ormerod and Duckworth (1975) reviewed a number of studies from both the USA and the UK and identified a number of common stances held by students that could be referred to more generally as attitudes. In particular, they identified as separate concepts attitudes to science and attitudes to school-science, the relative difficulty of the physical sciences in comparison to the biological sciences and other subjects, and the interest and enjoyment of science as a subject (1975, p. 4). Furthermore, they suggested that some of the artificial constraints inherent in a school system could be inadvertently influencing students' attitudes in a negative way, particularly in regards to student self-efficacy. They suggest that a possible hypothesis for the perception of higher relative difficulty of the physical sciences compared to other subjects offered at school could be that the physical sciences are syllabus heavy, content driven and are only made available to students of better than average intellectual capability. Thus the reputation of the physical sciences was such that students who express a dilettante interest in the subject were discouraged from pursuing that path (Ormerod & Duckworth, 1975, p. 21). In blunt terms, Ormerod and Duckworth were pointing to the establishment of self-perpetuating stereotypes as being fundamental in forming attitudes towards science.

Gardner (1975) reviewed the published research in regards to students' affective attitudes towards science, giving prominence to studies that measured interest satisfaction and enjoyment. The review classified the many types of attitude instruments utilised by other researchers and highlights some of the advantages and issues associated with each methodology. Gardner notes (1975, p. 10) that some studies utilised senior enrolment rates as an indication of positive interest towards that subject. However, the ensuing discussion and other research (e.g., Archer et al., 2012; Barnes, 1999; DeWitt et al., 2013; Lyons, 2006; Lyons & Quinn, 2010) suggests that while this link appears reasonable, it is likely a vast oversimplification of the underlying mechanisms, with structural variables—such as gender, socio-economic status or school sector—also influential in the enrolment decision.

Of all the criticisms made by Gardner of attitude instruments examined by Gardner, he is most critical of instrument reductionism (Gardner, 1975, p. 13)—that is reducing attitudinal measurement to a single total score—and warns that the richness of data that comes from genuine complexity and the generalisability of findings will be lost when simplified to a single dimension. With the benefit of hindsight, it is apparent that the lack of a definition for *attitudes* as a readily understood and transferable concept may have been central to this confusion surrounding attitudinal constructs; however Gardner's advice appears to have been heeded by subsequent researchers resulting in many studies (e.g., Barnes, McInerney, & Marsh, 2005; Farenga & Joyce, 1998; Khoo & Ainley, 2005; Lee & Bryk, 1986) that focused only on a single attitudinal aspect in the following years; few researchers have tackled student attitudes in the context of a spectrum of attitudes towards the broad school curriculum.

Throughout the 1980s Simpson and Oliver (1990) lead an extensive empirical study in the USA seeking to understand the relationship between science attitudes and science attainment in terms of 15 independent variables relating to home, school and self. Their collected data were wide ranging in their sources—coming from teachers, supervisors and students—as well as both longitudinal and cross-sectional. In keeping with the understandings of Gardner (1975) and Ormerod and Duckworth (1975), Simpson and Oliver focussed much of their research on the self-related variables of achievement motivation, anxiety towards science, student sex, and self-concept—both in science and more generally. In general they found that positive attitudes tended to decline between the beginning and end of each school year and also declined slightly as students progressed through school from kindergarten to Year 12. They also concluded that while male students tended to have more positive attitudes towards science than females, females were more motivated to achieve in science. Overall, they concluded that “male and female adolescent students feel and behave toward science in much the same way” (Simpson & Oliver, 1990, p. 7). Interestingly, Simpson and Oliver also found a link between changing attitudes and student abilities (cf. Ormerod & Duckworth, 1975) noting that the attitudes of students of middle ability tended to decline more rapidly than both the advanced students and the students of basic ability.

A more recent summary review of the literature (Osborne et al., 2003) found that the majority of studies that focussed on attitudes towards science identified a number of common themes. Firstly they noted a gap existed between the attitudes ratings of male and female students, with male students tending to hold more positive attitudes towards science than females. Secondly, they found a declining trend in students’ attitudes towards science that persists throughout high-school; although they acknowledged that attitudes towards school in general also tend to decline through early adolescence. Finally, they note that relevance, particularly in terms of self-relevance as opposed to career or societal relevance, has a marked effect on students’ attitudes towards the individual branches of science.

To the earlier broad categories of “attitude towards [school] science” and “scientific attitudes”, as expressed by Gardner (1975) and Osborne et al. (2003), there was recognition of an additional category of “attitude towards societal science”. This takes account of the apparent contradiction between students positive attitudes towards science in general and their attitudes towards science as experienced in schools. The international Relevance of Science Education [ROSE] project (Sjøberg & Schreiner, 2010) highlighted this issue, where Jenkins and Nelson (2005) noted that school science is less popular than most other subjects at school, has not made students more critical of information, nor instilled in students the importance of science for our way of life. However, they also reported that students nevertheless believe that science itself is important and brings more benefits than drawbacks thus showing the separation of the societal-related attitudes towards science and self-related attitudes.

As all these earlier works have starkly shown, the concept of *attitude* lacks a coherent and consistent working definition in the literature. Simon and Osborne (2010, p. 239) noted that forming a systematic summary of the attitudinal development of students has been “bedevilled by a lack of clarity about what attitudes to science are”. The potential for generalisation of the findings has therefore often been limited due to these variable definitions of “attitude”. Kind, Jones and Barmby (2007, p. 873) attempted to address this confusion, and defined an attitude as “the feelings that a person has about an object, based on their beliefs about that object”. This definition of attitudes will be adopted in the remainder of this thesis, where in the context of schooling, the “object” will be considered to be the individual school subjects studied by the students.

It is also very clear that the concept of attitudes is multifaceted; that is to say that students hold more than one attitude towards science—and by reasonable extension to other school subjects—at the same time. These attitudes are able to interact and influence each other (Gardner, 1975; Simpson & Oliver, 1990) as well as interact with and be influenced by other external structural variables such as social stereotypes and student sex. Thus any attempt to understand the problem of enrolments in terms of issues of attitudes needs to accept a level of complexity and uncertainty as part of the explanation.

Attempts to model students’ science enrolment decisions

Fishbein and Ajzen (2011) offer an approach to understanding human behaviours known as “reasoned action”. This approach argues that a person’s intentions towards an object follow in a consistent and reasonable manner from their attitudes towards that same object. It must be noted that Fishbein’s and Ajzen’s approach does not require that the action be rational nor deeply deliberated before being performed (2011, p. 24). Responses that are spontaneous or automatic can be considered to be reasoned action as they will still be based on previously formed attitudinal foundations that may have been adopted at the subconscious level. Based on this approach, it is reasonable to suppose that students’ enrolment decisions might be based at least in part on the attitudes they hold. However, the research evidence for a simple causal link between attitudes and intention to participate in science and mathematics courses such as might be predicted by this theory has proven to be problematic. While the reviews of the literature (e.g., Gardner, 1975; Ormerod & Duckworth, 1975; Osborne et al., 2003, 2009; and more recently Potvin & Hasni, 2014) tend to agree that attitudes have a substantial influence on young peoples' future study or career orientation, they nevertheless acknowledge that further research is needed to clarify the nature and mechanisms of this influence.

The research methods adopted over the years have tended to fall into one of two classes. Earlier researchers tended to adopt a positivist paradigm and thus adopted a highly quantitative approach to data collection and analysis. A frequent goal of these studies was the formation of a mathematical predictive model that could be utilised in explaining students' enrolment decisions. This nomothetic approach to students was successful in describing general patterns and influences but was unable to yield a simple model to predict enrolment intentions. Later researchers tended to adopt an interpretivist sociocultural paradigm in their studies with a resultant shift towards qualitative methodologies. This idiographic approach towards students placed greater emphasis on interview and observation than the earlier studies and sought to construct meaningful explanations for students' enrolment decisions through dialogue.

Quantitative approaches

Dekkers et al's (1986) study suggested the existence of four explanatory influences for the reported early declines in student participation in science, three of which might be summarised collectively as negative *attitudes*. However, they also suggested that a more compelling explanation for these changes in science participation rates might have been primarily an artefact introduced by increased Year 12 student retention. Effectively they argued that the additional students who chose to stay at school into Year 12 were not necessarily inherently motivated to study the sciences. Their later study (Dekkers & de Laeter, 2001) however, showed that even when retention rates stabilised around 1992, apparent participation rates in science continued to decline, and even actually accelerated in some areas. They also found a strong link between participation rates and the changing sex-balance of the year 12 cohort within science courses.

Fullarton et al. (2003), however, showed that the overall ratio of male to female Year 12 students did not greatly change in the period 1976 to 1998 even though the science participation gap between the sexes did widen to around 10% difference. They postulated that the compulsory core of science taught in Australian high-schools was, at the time, the most unsatisfactory part of the school science curriculum and in particular the fact that secondary schools did not generally recognise the knowledge developed by students in primary schools. This hypothesis was in agreement with the findings of Speering and Rennie (1996) who studied a cohort of Western Australian students as they transitioned from primary school to high-school. They argued that the negative attitude of students towards the core content of school science lead to students, in particular girls, becoming disenchanted with secondary science and therefore resulted in lower participation in the post-compulsory years.

Simpson and Oliver (1990) attempted to develop a prediction model for the formation of a commitment to science based on the formation of student attitudes. They noted that two groups of external influences, those relating to self and those relating to attitudes in the home, were instrumental in forming early attitudes towards science which were then developed and shaped as students progressed through school. While they were able to develop a framework (Figure 2.1) that ostensibly links the developments of positive attitudes to the different phases of the schooling process, they were unable to develop a reliable, predictive, mathematical model of the process. They noted that their framework and basic model was much more successful in identifying students who would not follow the science stream than the specific paths of those students who did choose to follow a scientific path.

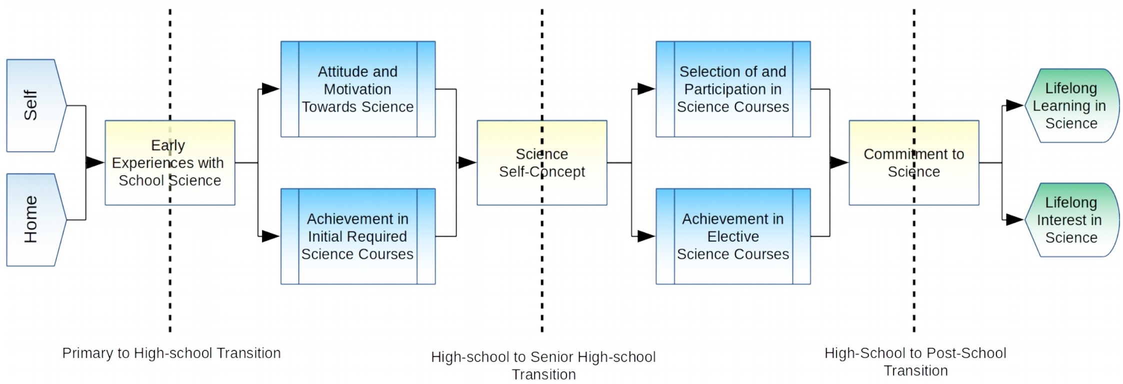

Figure 2.1: Influences and decision making factors that lead to lifelong interest in science based on Simpson and Oliver (1990).

The colour in this representation has been added to clarify the steps of the framework. Blue arrows indicate concrete influences acting on the student from outside the school system. Blue rectangles indicate processes that a student participate in within the school system. Yellow rectangles indicate the formation of self-related internal attitudes towards science. Green arrows indicate resultant decisions and/or behaviours.

Fullarton et al. (2003) performed a multivariate analysis that suggested the effect of six background influences on a student's subject enrolment decision that they believed were key to understanding student participation trends in science courses: student sex, socio-economic status, ethnicity, school sector, geographic location and prior scientific achievements. The descriptive analysis of Fullarton et al. is outlined in the pictorial representation presented in Figure 2.2. In this depiction, I have elected to break down socio-economic status into two sub-variables relating to parental education and occupation in keeping with the attitudes research of Gardner (1975) and to also break down geographic location into two sub-variables, state or territory and region, to acknowledge the in-built variation in both curricula and resources across the Australian education system. Figure 2.2 is not intended to indicate a specific or intentional process; it simply serves to graphically represent, in general terms, the effect of external influences on students as they make their school subject enrolment decisions.

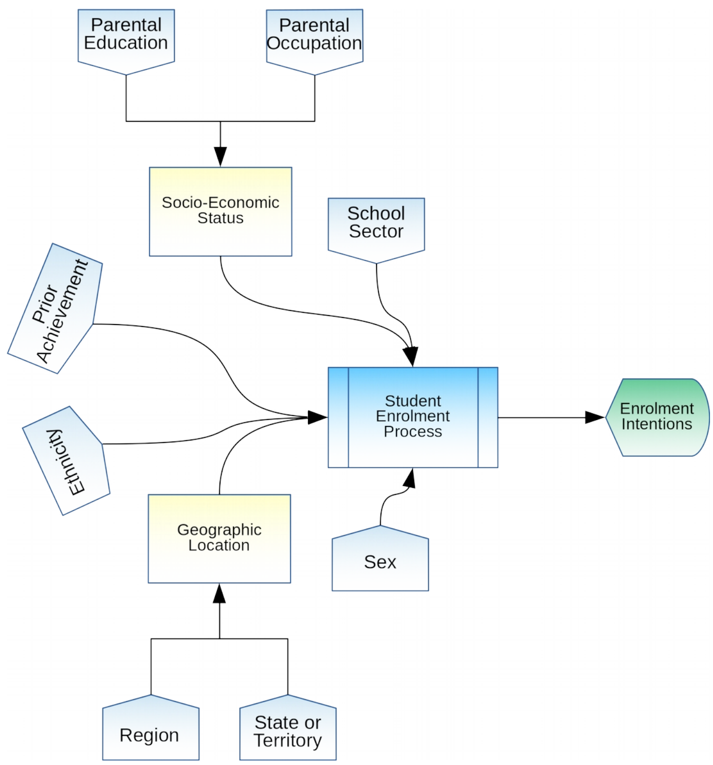

Figure 2.2: A graphical representation of the background influences approach to understanding student enrolments based on the analyses of Fullarton et al. (2003).

Blue arrows represent concrete external influences that can effect a student's enrolment decision process (Blue rectangle). The yellow rectangles in this diagram represent single influences that were identified by Fullarton et al., and represent composite ideas, that have been replaced with two example sub-factors for the purposes of measurement.

Eccles (1983) developed a general model of academic choice to explain achievement or choice motivation based on student expectancies and values. Although originally developed to understand choices and performance within mathematics, it was modified by Wigfield and Eccles (2000) so as to be more generally applicable. They postulated that a particular child's performance, persistence and overall choices in tasks are driven by that child's expectancies for success in those tasks and the subjective values they attach to them. They stressed that the expectancy of success used in the model is a measure not only of the child's own self-belief in their ability but also in their belief in their ability compared to their peers. They also comment that attainment value—the child's perceived worth of the end state or importance of doing well on the given task—often deals with how central the task is to the child's own sense of self; that is, attainment value asks the question, "is the task of intrinsic value or utility value to that child?".

Barnes (1999) developed the Science Enrolment Model from the General Model of Academic Choice of Eccles (1983) to explore the relationships between various influences on enrolment behaviour with specific relevance to post-compulsory science courses. Barnes explains this model in terms of exogenous and endogenous variables which, although useful, may appear a little mechanistic. An exogenous variable is considered here to be an influence that is external to a student but pushes *information* into the student and can inform an internal decision making process. Alternatively, an exogenous variable can be considered to be an external source of information or reference point that a student can call on to inform the decision making process. Expectations or encouragement of other people towards the student, or the student's willingness to involve themselves in social interactions and thereby shape their attitudes may be considered in many respects exogenous variables. For compatibility with other models, I shall refer to Barnes' exogenous variables as influences. Barnes considered endogenous variables to be internally synthesised variables that are held by the student and can actually effect the internal decision making process, but cannot themselves be easily measured. The endogenous variables of Barnes can be thought of as personal values and attitudes towards science.

Barnes (1999) identified three attitudes that had effects on students' science enrolment intentions: career value, interest value, and self-concept and performance expectations. Each of these attitudes were described as being constructed from or shaped by a number of influences relating to students' perceptions. For example, interest value was found to depend on a number of other influences—such as perceptions of encouragement and self performance expectations. Barnes also noted that interest value was able to influence career value within the model; that is to say his model was able to utilise interest value both directly and indirectly (via career value) to explain a student's enrolment intentions. The science enrolment model of Barnes is reproduced as Figure 2.3.

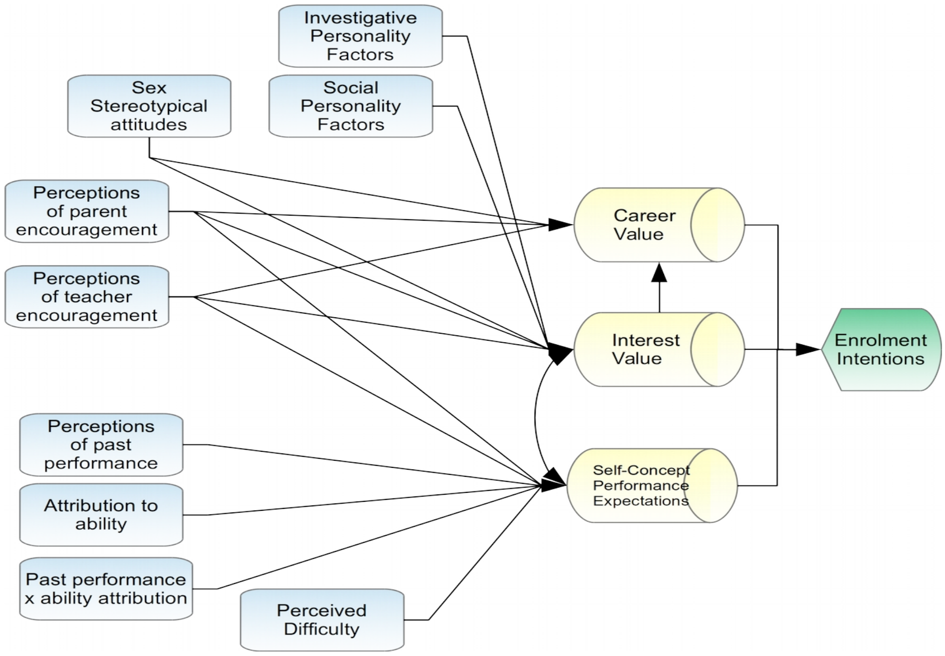

Figure 2.3: The Science Enrolment Model as proposed by Barnes et al. (1999).

The colour has been added to this model to highlight similarities with other models. Blue rectangles represent influences that can effect a student's internally formed attitudes (yellow). The green arrow represents the behaviours and/or actions that result from the formed attitudes of the student.

Regression analysis by Barnes, McInerney and Marsh (2005) was performed on the results of 450 completed questionnaires from five Australian high-schools to determine the path values for each exogenous variable and hence the path values for each of the endogenous variables on enrolment intentions in Barnes' (1999) model. For biology, chemistry and physics courses, the authors found that career value had the biggest influence on enrolment intentions and that the most significant factor in its synthesis was indirect interest value. It is interesting to note that for the physical sciences the authors reported that direct interest value was much lower than for biological science but that self-concept and performance expectations were much higher. This supports the findings of Lyons (2006) who showed that students perceived the physical sciences as being more difficult than the biological sciences—hence the need for self-belief in performance—and as having more utility value in applying for tertiary study, thus explaining why students enrol in physical science even though they expect not to be directly interested by the subject.

Qualitative approaches

Lyons (2006) approached the problem of understanding enrolments from a more sociocultural perspective. Starting from a multiple-worlds framework, based on the work of Phelan, Davidson and Cao (1991), he sought to try to distil and describe the very many factors affecting the enrolment decisions of high achieving Year 10 students towards science courses from the students' own experiences.

Phelan, Davidson and Cao (1991) pictured a student as being at the intersection of three mutually exclusive *worlds* namely family, school and peers/friends. They envisaged a student's day-to-day activities in terms of transitions from one world to another resulting in changes in behaviour and expectations. Lyons (2003, 2006) initially modified this model (Figure 2.4) to include a mass media world to represent the potential sea of information that students pass through in their day-to-day lives. He also made the boundaries between worlds 'porous' and 'ill-defined' so as to better represent a student's real world. The added porosity of the worlds reflects the interactions that can occur with each other independently of the student. The characteristics of each world were described as either structural (e.g. family structure or curriculum structure), attitudinal (e.g. beliefs and values) or dynamic (e.g. relationships and processes).

Lyons' framework (2006) was further developed based on rich qualitative data obtained from semi-structured in-depth interviews with selected respondents. Four dominant themes emerged in the results that offered some explanation from the students' school worlds as to why these students chose not to enrol in post-compulsory science courses.

- The senior physical sciences in particular were perceived by the students as being more difficult than other courses on offer.
- School science was perceived as both too teacher-centred and too content-focussed.
- The typical school science curriculum was perceived as irrelevant and hard to engage with.

- Senior physical science courses were considered only of strategic value for entry to tertiary study.

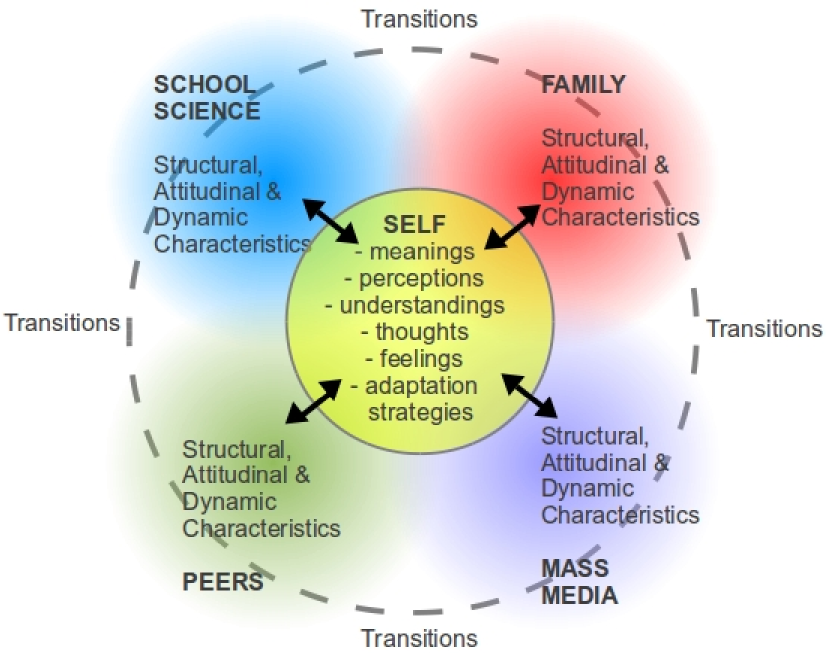

Figure 2.4: Multiple worlds model of student enrolment behaviour as and presented by Lyons (2003, 2006) and initially proposed by Phelan et al. (1991).

Additional analysis of the narratives identified parental attitudes to formal education, and to science in general, as having a strong secondary influence on the enrolment intentions of students. Lyons (2006) explains that science-proficient students were more likely to choose to enrol in physical sciences when the negative aspects of the school science world are mitigated and made tolerable by the positive aspects of their family worlds, and concludes that the single most important factor in the decision of many students not to enrol in physical science courses is the existing culture of school science itself (Figure 2.5). That is to say, even though physical sciences have apparent utility value and status within the Australian education system, they are perceived by students to have fewer intrinsically satisfying features than they might have.

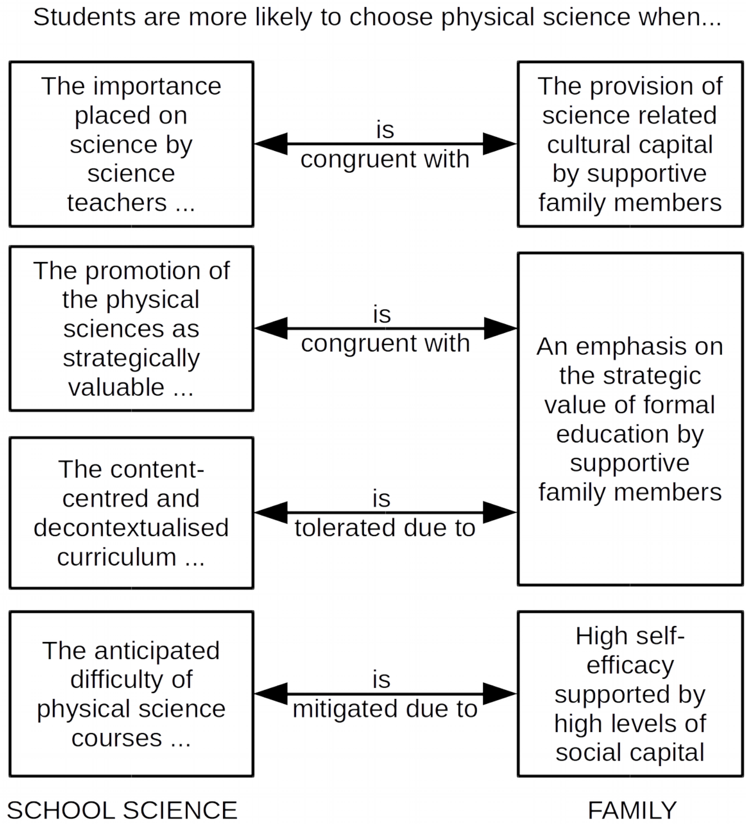

Figure 2.5: Lyons' (2006) model showing the interplay of characteristics from school science and family worlds for science proficient students who chose to study physical science courses in high-school.

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Lyons and Quinn (2010) examined the rationales and perceptions of individual year 10 students and science teachers towards post-compulsory science. Through the use of two online survey instruments they were able to describe both the students' perceptions and attitudes towards the sciences as a school subject and also science teachers perceptions of the influences on students' enrolment decisions. They found that the declines in participation seen in the science subjects by Dekkers and de Laeter (2001)and Ainley et al. (2008) were part of a broad phenomenon affecting many of the traditional senior school subjects and not just isolated to the STEM domain. They proposed that a changing context for enrolment choices in senior high school together with a set of interrelated factors were driving the observed changes.

While Lyons and Quinn (2010) showed that the declines in science enrolments appeared to be caused by significant systemic changes within the Australian education system as a whole, they highlighted the reduction of prerequisite courses for university and the greater breadth of choice available to students in Year 11 as being a likely key to understanding the changing enrolments in science. In particular, they showed that this increased subject choice appeared to result in the formation of three concerning situations with respect to school science that required addressing:

- The difficulty many students have in perceiving themselves undertaking scientific careers
- The decrease in utility and strategic value of science courses relative to their perceived difficulty
- The relative failure of school science to engage the full range of students within the context of a broader “open-market” of subjects.

It is interesting to note that the authors stress that it is the perceived difficulty of science relative to the rewards of participating in the courses that appears to have impacted participation in the sciences. As physical science courses are no longer considered prerequisites by universities, it could be considered likely that the reluctant-students of previous cohorts, who may have selected a science course due to need rather than desire, are today choosing subjects that they perceive as having a greater benefit for lower perceived cost or risk.

Attitudes in mathematics and other STEM fields

Historically, courses teaching engineering thinking and skills have not been widely available in schools in Australia, and only became available in most states and territories in the mid 2000s. The traditional lack of this subject area in schools has meant that there is a very small corpus of knowledge regarding this discipline and student attitudes towards it. While courses in technology have been widely available for a long time, they have generally encompassed a wide range of course specific skills and knowledge—ranging from textiles to design technology and computing to graphics. This broad nature of the discipline area has result in a collection of research that has been, to the main extent, narrowly focussed on particular courses and contexts (e.g., Bell, Andreae, & Lambert, 2010; Brinda, Puhlmann, & Schulte, 2009; Carter, 2006; Hill, Corbett, & St Rose, 2010).

However, while the data and studies on attitudes towards school engineering and technologies have been sparse, much has been written about the state of mathematics in

Australia. In conjunction with their work on science, Dekkers, de Laeter and Malone (1986; 2000) investigated the shift away from the more academically challenging mathematics courses towards courses that were perceived at the time as being less rigorous. At the time of the writing of their 2000 paper, the authors were clearly concerned that the reduction in mathematical competency of school leavers had the potential to impede the country's ability to compete in a competitive and increasingly technological world. Barrington (2006) and Forgasz (2006) both showed that these trends continued well into the twenty-first century with both advanced mathematics and intermediate mathematics participation rates steadily declining even though the total participation in mathematics rose slightly in the same period due to the growth of elementary-level mathematics.

Other researchers (e.g., Calderon, Dobson, & Wentworth, 2000; Norwich & Jaeger, 1989) indicated the existence of strong links between self-efficacy, positive attitudes and positive learning outcomes in mathematics, as well as a strong correlation between higher level mathematics study and higher overall student performance against curriculum outcomes. The benefits to be potentially gained from a study of higher level mathematics thus seem at odds with the declining trends in mathematics enrolments previously identified (e.g., Ainley et al., 2008; Barrington, 2006; Dekkers et al., 1986; Dekkers & Malone, 2000; Forgasz, 2006). Indeed McPhan, Morony, Pegg, Cooksey, & Lynch (2008) investigated this very phenomenon and identified that attitudes relating to self perceptions, interest, usefulness and relative difficulty were key to explaining the changing participation in mathematics. This list of attitudes and influences is almost identical to those identified as being key to understanding the similar trends seen in science (Osborne et al., 2003).

Successive reports of Australian performance in the Trends in International Mathematics and Science Study (e.g., Thomson, 2009) showed that while the performance of Australian students in mathematics remained consistent over a period of around ten years, the performance of other countries improved markedly. A number of research groups (e.g., Chinnappan, Dinham, Herrington, & Scott, 2008; McPhan et al., 2008) identified a number of areas of concern about Australian school mathematics, in particular around the content heavy nature of the curriculum, the lack of perceived relevance of the curriculum and the quality and quantity of mathematics teachers available to deliver it. Bursal and Paznokas (2006) identified comparable issues in the USA which they explained through the mathematics anxiety (defined in Trujillo & Hadfield, 1999) of pre-service teachers. Merging the reported declines in participation in higher level mathematics with the issues of confidence and anxiety observed in pre-service teachers by Bursal and Paznokas (2006) demonstrates the feedback power of negative attitudes reinforcing the formation of lower self-efficacy in mathematics.

Outlining an integrated theoretical framework

The quantitative studies of Fullarton et al. (2003) , Dekkers and de Laeter (2001), and Barnes et al. (2005) are able to provide good descriptions of the issues and influences surrounding enrolment decisions at the macroscopic level, while the qualitative approaches of Phellan et al. (1991) Lyons (2006), and Lyons and Quinn (2010) are able to provide good explanations of the sociocultural interactions and influences on the local scale. However, while both classes of study have been able to identify potential causes for the observed declines in STEM subject participation at the high school level, both approaches are also limited in their generalisable explanatory power. Yet together, the two approaches offer complementary and rich perspectives on the phenomena of declining enrolments.

In order to try to marry these two complementary approaches I shall adopt a theoretical framework that is a hybrid of the model presented by Barnes (1999) and the initial model presented by Lyons (2003). This framework is shown as Figure 2.6. In this view, the student is pictured as being at the focus of three semi-independent worlds; school, home, and media. Peers and friends, from the model of Lyons, are proposed to be found straddling the boundary of the home world and the school world. Within this framework, information is considered to flow from these worlds towards the student as well as between worlds. Under normal conditions these flows should be considered to be bi-directional so that students are able to influence and be influenced by others; however, in the context of reasoned action (Fishbein & Ajzen, 2011) they become inward facing. From outside of the student's universe (dotted line), information can flow from external factors—such as government policy, university entrance requirements, or syllabus requirements—into the system to alter the student's worlds, yet these external factors are unable to directly interact with the student. This is a mechanism that is similar to the exogenous variables interacting with the endogenous variables of Barnes' (1999) approach.

The student is then imagined to be described by a number of characteristics; some intrinsic or unchanging characteristics—at least in the short term (e.g. sex, ethnicity, socio-economic status of family, etc. (Fullarton et al., 2003)), and some as dynamically formed attitudes (e.g. perceived academic ability, career aspirations, etc. (Gardner, 1975)). Other, external influences from the student's various worlds provide information to the student as a decision maker, and help to shape the student's attitudes to differing extents. The intrinsic characteristics of the student then act as a filter or lens through which these attitudes are further shaped, clarified and tempered. Finally the framework suggests that the attitudes held by the student become manifest when utilised in making decisions through the process of reasoned action. These various interactions are imagined as shown in Figure 2.6.

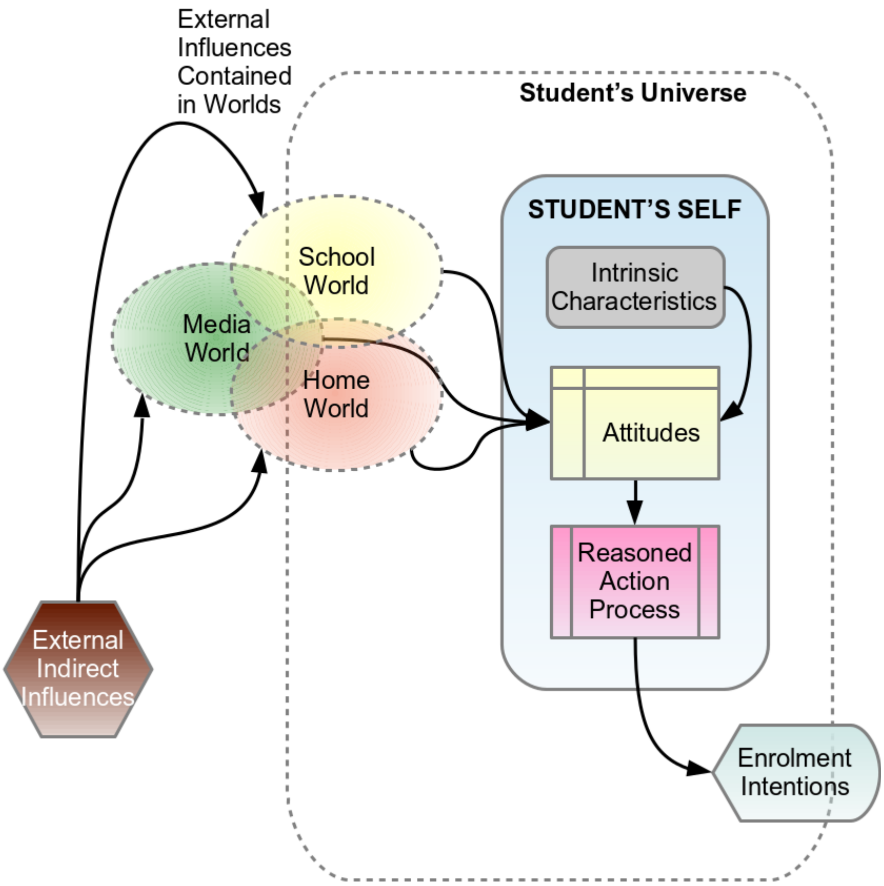

Figure 2.6: Understanding how variables from different student worlds influence the student's actions as the director of their decision making process.

As already discussed, there are a great number of external influences identified by previous studies that appear to influence positive attitudes towards science or that elicit positive enrolment decisions (e.g., Gardner, 1975; Lyons, 2003; Lyons & Quinn, 2010; Ormerod & Duckworth, 1975; Osborne et al., 2003, 2009; Simon & Osborne, 2010; Simpson & Oliver, 1990). Figure 2.7 attempts to summarise these variables and influences into an interaction map and assign them to various interactions between the student and their worlds as well as between the worlds themselves. As can be seen a significant number of these relate to concepts of self-concept, career usage and relevance, and personal interests and enjoyableness of a subject. The complexity of the formation of attitudes and the process of decision making through reasoned action is also particularly highlighted by this interaction map. The number of interactions shown in this diagram emanating from the school world, and indirectly from the peers and friends intersection of worlds, is strongly indicative of the particular influence of a student's peers on such a decision making process. This is in keeping with the understandings that studies such as Lyons and Quinn (2010) have elucidated in this area.

In developing a deeper understanding of the student as a reasoned decision maker and attempting to synthesise the observations and predictive models of previous researchers, this framework Figure 2.6 begins to offer the possibility of a gateway into understanding how the formation of student attitudes and the changing enrolment patterns observed in the STEM subjects are intertwined.

Emergent trends in the literature

The seven and a half years of this study have seen a plethora of studies and reports from around the globe investigating individual aspects of the enrolments or attitudes issues previously described. The framework outlined in Figure 2.6 was developed prior to much of this work yet it is still valuable in helping understand the possible linkages between attitudes and enrolments. In Osborne, Simon and Tytler's update to attitudes surrounding science (2009), concerns about the inability of school science to engage teenage students are at the fore of the literature. The suggestion that students should be doing science rather than being a scientist (Archer et al., 2010) has been repeatedly lauded as a way forward in addressing engagement, particularly in the upper years of primary school. This shift in focus from the later years of secondary school towards the upper primary years (Turner & Ireson, 2010) comes as growing research suggests that attitudes towards science—in particular interest in science—are becoming less fluid at a younger age than previously thought. Potvin and Hasni (2014) examined a large number of attitudinal studies seeking to find links between interest, motivation and attitude towards science and technology. They conclude that attitudes towards science and technology have continued to decline with the number of years students spend in schooling but they were unable to determine if this is attributable to the school system or to student maturation.

However, this fairly bleak macroscopic view of attitudinal change is not the only story. Research evidence that expounds the positive effects of interest and engagement on student enrolment intentions formed in the junior years of high-school (Lyons & Quinn, 2010; Potvin & Hasni, 2014) has continued to be added to the body of literature, particularly when those efforts to improve attitudes have been well focussed and resourced. Researchers in the mathematics domain have also continued to highlight the reinforcing effects of prior achievement and positive attitudes on future enrolment intentions (Attard, 2015; Blackweir, 2016; Hemmings, Grootenboer, & Kay, 2011).

Yet, even with this focus on explanation, media attention (Ferrari, 2011; O'Keeffe, 2012; Thompson, 2011; Tisdell, 2014) has regularly focussed on the continuing discussion of the trends in STEM education and their relative utility for entry to tertiary education. However, even with a National STEM School Education Strategy (Education Council, 2015) and numerous agendas and visions for a technologically agile future economy (Commonwealth of Australia, 2015b, 2015a; Lowe, 2014) the answers to questions around how best to implement change and reverse decades of decline remain elusive.

A number of common themes have become evident when distilled from the more recent research. Emphasis on promoting STEM subjects as a gateway to future careers has increased (Aschbacher, Ing, & Tsai, 2014; Holmegaard, Madsen, & Ulriksen, 2014; Universities Australia, 2012) and combined with a desire for business and industry to recognise the value of STEM subjects (Deloitte Access Economics, 2014; Office of the Chief Scientist, 2013; Prinsley & Baranyai, 2015). In turn this synergy between the subject areas has become encapsulated within the Australian Curriculum—a new national level approach to education to unify the varied systems previously employed by the different states and territories—with the long term goal of increasing relevance and engagement with education and thus raising participation. There has also been a stronger spotlight shone on the disparity in participation between male and female students (Sadler, Sonnert, Hazari, & Tai, 2012; Zagami, Boden, Keane, Moreton, & Schulz, 2015) and between regional and metropolitan students (Lyons & Quinn, 2010; McPhan et al., 2008).

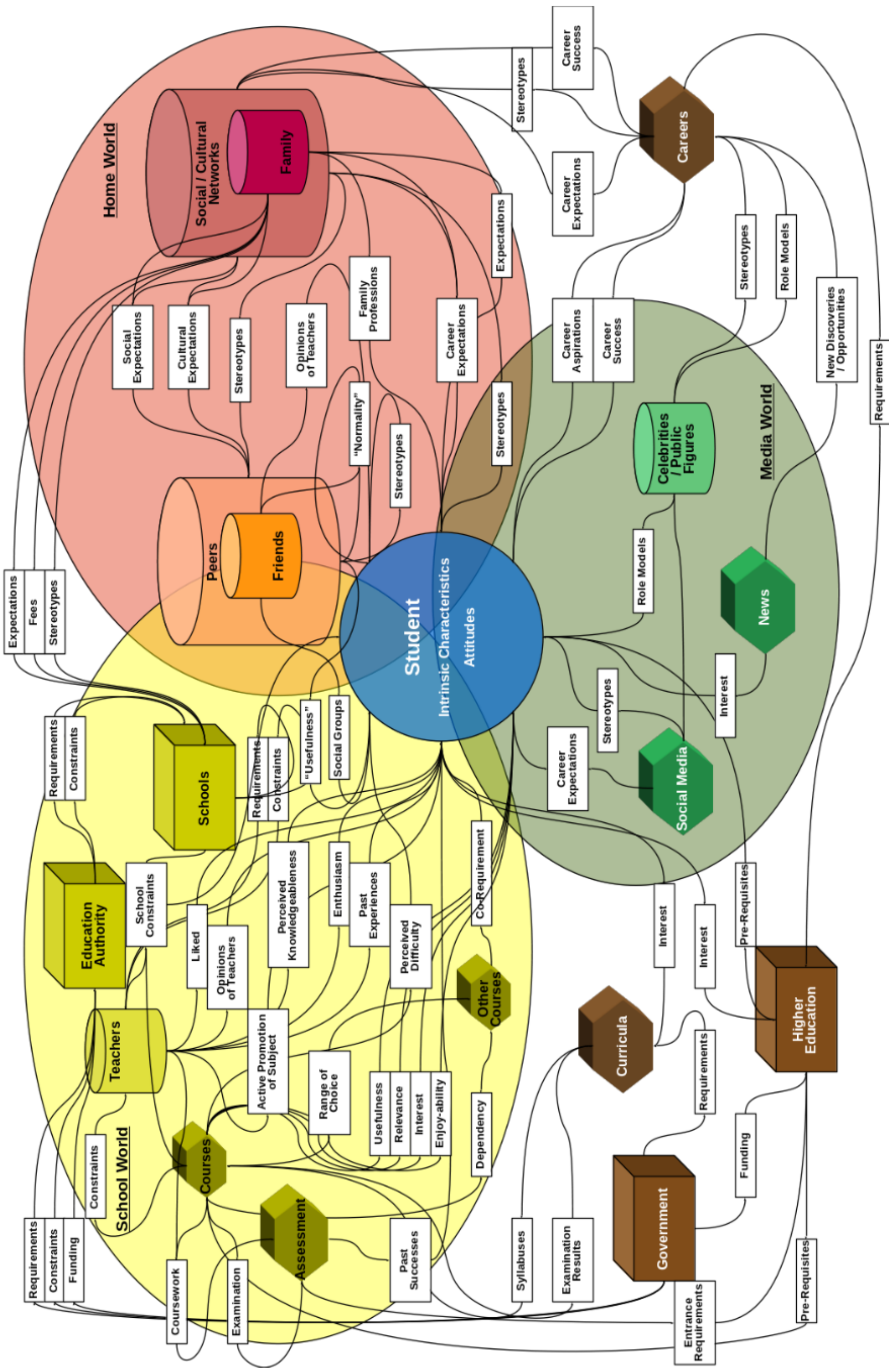

Figure 2.7: Interaction map of the various influences on the formation of student attitudes and behaviours.

This diagram highlights the interconnectedness of all the influences acting upon all aspects of a student's worlds and how they may be used to form and shape the student's attitudes. Note that although the world of peers and friends has been placed on the boundary of the school and home worlds, this does not mean that a student's friends must attend school. Friendships that exist outside the school context are considered to be part of the home world. In this framework, it is the student's attitudes (contained within the blue circle) that are directly utilised in the decision making process rather than the individual influences seen on the diagram.

Developing Detailed Research Questions

The literature described in the preceding sections of this chapter give rise to a number of research questions to be addressed in the remainder of this study. As described previously in Chapter 1, there are two general research themes that will be addressed.

RT1 What are the present enrolment trends in post-compulsory STEM disciplines in Australian high-schools?

In order to address the questions surrounding the causes and influences of the declines in enrolments across the STEM disciplines, it is essential that the data regarding enrolment trends be brought up to date. Ainley et al. (2008) was the most up to date source of information regarding enrolments in both science and mathematics courses at the outset of this research. This gives rise to the following research questions:

RQ1 To what extent are the reported declines in participation in high-school science and mathematics courses across Australia continuing into the second decade of the twenty-first century?

RQ2 What is the nature of the participation trends in the other STEM fields of technology and engineering?

RQ3 To what extent are the trends in participation similar and different between the various STEM fields and in what ways are they linked with broader curriculum offerings?

RQ4 To what extent does student sex influence the trends in participation across the STEM fields?

RQ5 To what extent do general patterns in school enrolments such as overall retention, impact on the participation rates in the STEM fields?

RT2 How do student attitudes towards STEM-related courses change over time in comparison with other school subjects?

Utilising the theoretical framework outlined in Figures 2.6 and 2.7 in order to form explanations for the observed patterns in participation, it becomes essential to consider both the attitudes of the student towards the subject(s) of consideration as well as their attitudes and characteristics more generally. In line with this framework, this study will focus on developing an understanding of how the attitudes of personal interest, subject enjoyability, career usefulness and relevance, and self-concept in and towards the STEM subjects change and develop over time and how these affect a student's attitudes towards school more generally. This gives rise to the following research questions:

RQ6 Can an instrument be developed to quickly measure students' self-reported attitudes towards their school subjects over time?

RQ7 To what extent do student attitudes towards STEM change and develop throughout the early years of high-school?

RQ8 What factors appear to affect students' attitudes and enrolment intentions towards further study in STEM fields?

These eight research questions will be developed and explored through the remainder of this thesis with Chapters 3 to 4 focussing on Theme 1 and its associated questions and Chapters 5 to 7 focussing on Theme 2. These questions will be revisited in the concluding chapter where common themes and patterns will be drawn from them.

2.3 Statement of authors' contribution

We, the PhD candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in this thesis and they have accepted the candidate's contribution as indicated in the Statement of Originality.

	Author's Name	**% of contribution**
Candidate	JohnPaul Kennedy	100
Other Authors		

[redacted]

JohnPaul Kennedy
(Candidate)

25th September 2018

[redacted]

Dr Frances Quinn
(Principal Supervisor)

25th September 2018

2.4 Statement of originality

We, the PhD candidate and the candidate's Principal Supervisor, certify that the following text, figures and diagrams are the candidate's original work.

Type of Work	Page Number/s
Figure 2.1	25
Figure 2.4	29
Figure 2.5	34
Figure 2.6	34
Figure 2.7	37

[redacted]
JohnPaul Kennedy
(Candidate)

25th September 2018

[redacted]
Dr Frances Quinn
(Principal Supervisor)

25th September 2018

Chapter 3: The continuing decline of science and mathematics enrolments in Australian high schools

3.1 Introduction

In Chapter 1, I established two research themes (p. 5) that guide the structure of this thesis. The article presented in this chapter begins to address the first of these themes, "What are the present enrolment trends in post-compulsory STEM disciplines in Australian high-schools?", and in particular focuses on this theme in the context of school science and mathematics. This chapter is essential in beginning to answer research questions RQ1, RQ4 and RQ5 in that it continues the work of Dekkers, de Laeter and Malone (Dekkers & de Laeter, 2001; Dekkers, De Laeter, & Malone, 1986; Dekkers & Malone, 2000), Ainley, Kos and Nicholas (2008) and brings the published understandings of Australia wide enrolment trends in high-school science and mathematics up to date (2012 at the time of publication).

This data used in the analysis of this chapter were collected and collated from the published statistics of the various state and territory bodies responsible for Year 12 assessment. The collection methods I chose to employ are unique in that I did not constrain myself to just one state or just one curriculum area: these data represent 38 different course areas aggregated across all eight states and territories and combined with comparative data for Australian Year 12 students who were registered to complete their studies through the International Baccalaureate Diploma Programme. The summary tables of these data are presented in Appendix A to this thesis.

The article first places my research into the context of a so-called *crisis* in STEM education by reviewing the relevant literature pertaining to the measurement of enrolment trends in science and mathematics over a 20 year period. I then argue that, in a some cases, the reporting of various educational trends by the media and other stakeholders (e.g., Goodrum, Druhan, & Abbs, 2011) has not been entirely consistent with the data. The analysis of the existing literature also shows that classification and naming of science and mathematics courses offered in schools across Australia has been rather varied and at times seemingly arbitrary. Consideration of previous researchers' approaches to this problem leads to the proposal of a simplified naming scheme (Table 3.1 and Table 3.2) which is subsequently used throughout this thesis.

Finally the data are analysed and presented as a series of graphical representations of enrolments over time. Crucially, these graphs show that while enrolments in many subject areas have continued to decline, the rate at which they have done so has slowed in recent years. These patterns are essential in answering the research question, "To what extent are the reported declines in participation in high-school science and mathematics courses across Australia continuing into the second decade of the twenty-first century?" (RQ1). By comparing the enrolment trends for male and female students, as well as the total enrolments for schools, the data is also able to differentiate patterns of study that have significant male or female bias or that have declined in participation, even though the absolute number of graduates of that course has remained steady. These patterns in the data are critical for understanding the "influence of student sex on the trends in participation across the STEM fields" (RQ4) and the effect that "general patterns in school enrolments [… have] on participation rates in the STEM fields" (RQ5).

3.2 Journal Article 1

This article was originally published in "Teaching Science: The Journal of the Australian Science Teachers Association" (June 2014 | Volume 60 | Issue 2) available at http://asta.edu.au/generic/file-widget/download/id/862 or http://e-publications.une.edu.au/1959.11/15615

Cite this article as:

Kennedy, J., Lyons, T., & Quinn, F. (2014). The continuing decline of science and mathematics enrolments in Australian high schools. *Teaching Science: The Journal of the Australian Science Teachers Association*, *60*(2), 34–46.

3.3 Article Impact

At the time of submission of this thesis, this article had been cited 114 times based on Google Scholar metrics and has had wide ranging impact.

The continuing decline of science and mathematics enrolments in Australian high schools

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Is there a crisis in Australian science and mathematics education? Declining enrolments in upper secondary science and mathematics courses have gained much attention from the media, politicians and high-profile scientists over the last few years, yet there is no consensus amongst stakeholders about either the nature or the magnitude of the changes. We have collected raw enrolment data from the education departments of each of the Australian states and territories from 1992 to 2012 and analysed the trends for biology, chemistry, physics, two composite subject groups (earth sciences and multidisciplinary sciences), as well as entry, intermediate and advanced mathematics. The results of these analyses are discussed in terms of participation rates, raw enrolments and sex-balance. We have found that the total number of students in Year 12 increased by around 16% from 1992 to 2012 while the participation rates for most science and mathematics subjects, as a proportion of the total Year 12 cohort, fell (biology (-10%), chemistry (-5%), physics (-7%), multidisciplinary science (-5%), intermediate mathematics (-11%), advanced mathematics (-7%)) in the same period. There were increased participation rates in earth sciences (+0.3%) and entry mathematics (+11%). In each case the greatest rates of change occurred prior to 2001 and have been slower and steadier since. We propose that the broadening of curriculum offerings, further driven by students' self-perception of ability and perceptions of subject difficulty and usefulness, are the most likely cause of the changes in participation. While these continuing declines may not amount to a crisis, there is undoubtedly serious cause for concern.

Introduction

Is there a crisis in Australia's science and mathematics education? There has certainly been significant media coverage of this issue over the last few years, though the evidence provided appears confusing and at times even contradictory. A study commissioned by Australia's Chief Scientist concluded that all the main high school sciences were experiencing continuing and dramatic declines (Goodrum, Druhan, & Abbs, 2011). However, the scale of those reported declines has since been questioned (Ferrari, 2011) leading to confusion over the actual figures. Whatever their true scale, it is clear that government and industry bodies believe that these declines in science and mathematics education need to be addressed.

At the senior high school level a number of reports (e.g., Ainley, Kos, & Nicholas, 2008; Dekkers & de Laeter, 2001; Hackling, Goodrum, & Rennie, 2001; Hassan & Treagust, 2003) point to either a decline in science education enrolments in Australia or, at best, zero growth over the long term. Studies into the state of mathematics (Barrington & Brown, 2005; Thomson, 2009) have reported similar levels of decline in participation.

The trends reported in Australia have been echoed to various extents in a number of countries across the globe including England and Wales (Smith, 2011), France (Charbonnier & Vayssettes, 2009), India (Garg & Gutpa, 2003), Israel (Trumper, 2006), and Japan (Schleicher & Ikeda, 2009) thus suggesting that the causes of the changes may go beyond national and cultural borders.

It is important to resolve these conflicting messages and clarify the state of enrolment trends in high school science and mathematics courses. This is especially so given the increasing requirement for citizens to make informed decisions about socio-scientific issues such as renewable energy production, coral reef degradation or climate change. Furthermore, analyses of previous trends in Australia are now several years old and it is crucial that policy and planning initiatives are based on the most accurate and up to date information. This is especially true given the expense of education and the current context of funding (Kelly, 2013).

This paper provides a fresh analysis of Australian senior high school science and mathematics enrolment trends over the last two decades, based on recent state and territory enrolment data. The trends in the participation rates are discussed here both individually and in the wider context of school science. Some of the confusion surrounding the trends is clarified and we show that enrolments in the majority of science and mathematics courses are continuing to decline. To fully understand these trends requires a deeper analysis than can be offered in this paper; however some general conclusions and recommendations are offered here.

Background

To understand the context of senior school enrolments in Australia requires an overview of the education systems across the country. There are presently ten recognised school-leaving qualifications administered by eight individual state and territory governments and one international organisation (Masters, Forster, Matters, & Tognolini, 2006). Depending on jurisdiction, students variously start secondary schooling in either Year 7 or Year 8, aged 12 or 13 years old, and are legally required to remain in compulsory education, employment or training until the age of 17. Prior to 2010, the compulsory school age varied between 15 and 17 on a state-by-state basis. Across all states and territories, English, Mathematics and Science are compulsory subjects until the end of Year 10 and English remains compulsory in Years 11 and 12 except in the Australian Capital Territory (ACT). Students generally select a further three to five other subjects from those offered by individual schools to complete their senior studies. Alternative curricula such as the International Baccalaureate (IB) add a layer of complexity, with IB enrolments accounting for around 0.8% of total Year 12 enrolments in 2012. Throughout this paper we have used the term enrolment to mean students who have enrolled in a school in Australia in their final year of education and have been presented for matriculation to their state education body. Enrolment does not necessarily refer to successful completion of the course.

An important issue to consider in interpreting enrolment trends is the classification used to refer to the multitude of course options across disparate educational jurisdictions. The classification of the “core” science subjects, biology, chemistry and physics, across Australia is fairly straightforward and consistent. However, other science courses have been included in historical analyses and categorised variously at different times (Table 3.1). In this paper we also consider the groupings earth sciences and multidisciplinary science. We note that while Hassan and Treagust (2003) and Ainley et al. (2008) included psychology as a science course, its unavailability in some high population states and its promotion elsewhere as a social science have led us to exclude it from this discussion for the sake of clarity.

Table 3.1: Science Subjects historically analysed by previous researchers.

<table>
<tr><th>Subjects Analysed</th><th>Dekkers and de Laeter (2001)</th><th>Hassan and Treagust (2003)</th><th>Ainley, Kos and Nicholas (2008)</th><th>Kennedy, Lyons and Quinn (2014)</th></tr>
<tr><td>Biology</td><td rowspan="2">✔</td><td rowspan="2">✔</td><td rowspan="2">✔</td><td rowspan="2">✔</td></tr>
<tr><td>Human Biology</td></tr>
<tr><td>Chemistry</td><td>✔</td><td>✔</td><td>✔</td><td>✔</td></tr>
<tr><td>Physics</td><td>✔</td><td>✔</td><td>✔</td><td>✔</td></tr>
<tr><td>Geology</td><td>✔</td><td>✔</td><td>✔</td><td rowspan="2">✔</td></tr>
<tr><td>Environmental Science</td><td></td><td></td><td></td></tr>
<tr><td>Agriculture</td><td>✔</td><td></td><td></td><td></td></tr>
<tr><td>Alternative Science</td><td>✔</td><td rowspan="4">✔</td><td rowspan="4">✔</td><td rowspan="3">✔</td></tr>
<tr><td>Physical Science</td><td></td></tr>
<tr><td>General Science</td><td></td></tr>
<tr><td>Other Sciences</td><td></td><td></td></tr>
<tr><td>Psychology</td><td></td><td>✔</td><td>✔</td><td></td></tr>
</table>

Classification of mathematics courses has proven to be equally complex. Courses tend to be defined depending on their content or on their pathways to tertiary education. Table 3.2 shows the historical classification of the mathematics courses and their general content. Although these categories seem clear-cut, to categorise a particular mathematics course fairly requires analysis of the content of course syllabus which, in some cases, is very difficult. Furthermore a subset of elementary mathematics courses is not able to be included in the calculation of Australian tertiary admission ranks (ATAR). For the purposes of this analysis the elementary mathematics group is therefore split into background mathematics and entry mathematics.

Table 3.2: General classifications of Australian high school mathematics courses.

Dekkers, de Laeter and Malone (2000) classification	Barrington (2006) classification	Kennedy, Lyons and Quinn (2014) classification	General Course Content
Low	Elementary	Background	Terminal mathematics courses that are not designed for further tertiary study and do not contribute towards tertiary admissions rank.
		Entry	Terminal mathematics courses that are not designed for further tertiary study yet do contribute to the calculated tertiary admissions rank.
Intermediate	Intermediate	Intermediate	Mathematics courses that provide a satisfactory knowledge-base for tertiary courses requiring minimal understanding
High	Advanced	Advanced	Mathematics courses that provide a specialised knowledge-base for tertiary studies in courses such as engineering and physical science.

Previous studies of Australian science and mathematics enrolments

Dekkers, de Laeter and Malone (1986) began a systematic process of tracking Year 12 student enrolments in science and mathematics with follow up studies at the turn of the millennium (Dekkers & de Laeter, 2001; Dekkers & Malone, 2000). These reports showed that as the proportion of students continuing beyond post-compulsory education increased, science enrolments slowly but steadily climbed to a peak around 1992 before falling away towards the end of the decade. They also found that intermediate mathematics enrolments followed a very similar pattern to science enrolments, coinciding in their peaks in 1992, yet advanced mathematics enrolments declined steadily through the period. Hassan and Treagust (2003) expanded on these studies by considering the declines in science and mathematics in the context of other key learning areas (KLA).

Dekkers et al. (1986) attributed much of the observed increases in both science and mathematics enrolments to increased retention, particularly female retention, into Year 12. Some researchers (e.g., Hackling et al., 2001; Hassan & Treagust, 2003) suggested that course content and financial and career incentives may be key to understanding the subsequent declines. However, studies by Lyons & Quinn (2010) and Thomas (2000) suggest that the declines in were likely to be a consequence of diversification; both of the academic and career aspirations of the expanded Year 12 cohort and the associated diversification of curriculum offerings, including the introduction of alternative and vocational courses. Forgasz (2006b) noted that declines in mathematics appeared to be part of a trend away from more specialised mathematics courses towards elementary courses, rather than a decline in total enrolments.

Ainley et al. (2008) extended these science trends to 2007 and showed that from 2000 the actual numbers of students enrolled in Year 12 science courses appeared to be very slowly recovering. However, while the number of students in science classes grew slightly, this increase was vastly outstripped by the increasing numbers of students completing Year 12. This was reported as a continued decline in terms of student participation rates in science.

Barrington and Brown (2005), Barrington (2006) and Forgasz (2006b) continued previous work on mathematics enrolments, showing that downward trends in both intermediate and advanced mathematics continued to 2004, while in elementary courses enrolments continued to increase. Forgasz (2006a) reported large differences in enrolments in intermediate mathematics between states and concluded that variation in student expectations of different courses may be key to explaining the observed decline in enrolments at the intermediate level. In her view, the mathematical ability required of students studying at the intermediate level in some states was much greater than at the elementary level, yet this was not necessarily equitably rewarded in their final marks. Barrington (2013) showed that while enrolments in advanced mathematics seemed to be reasonably stable, the trend for students to select elementary mathematics in preference to intermediate has persisted.

Methods

Data Collection

State and territory curriculum authorities publish raw enrolment data annually for every Year 12 course in a variety of forms including media guides and annual reports to government, and the national statistics presented here were compiled from these individual raw data sets. The year 1992 was selected as a science base-level as the work of Dekkers and de Laeter (2001) had already shown this as the year in which participation rates peaked and retention rates from Year 10 to Year 12 stabilised at around 75%. There were also major curriculum changes in a number of states and territories around this time, so inclusion of data from earlier years would not clarify the enrolment trends of the twenty first century. The year 1994 was selected as the base-level for mathematics enrolments (in keeping with Barrington and Brown (2005)) since categorising courses prior to this is unreliable due mainly to course designations in Victoria (VIC).

Definitions and Constraints

Each of the different state and territory boards offers science subjects under slightly different titles. In this study, enrolments for biology also include enrolments for human biology. Some boards offer geology, environmental science, and earth and environmental science; and here these are grouped under the term earth sciences. Similarly some less specialised science courses such as senior science in New South Wales (NSW), integrated science in Western Australia (WA) and science21 in Queensland (Qld) are available, and are here grouped as multidisciplinary science.

To allow for valid comparisons between states and over time (due to variations in course curricula), only enrolments in the highest level course available (see Table 3.3) are included in this analysis. Even though this data collection context is slightly different to that of earlier researchers, results presented here are consistent with earlier works (Ainley et al., 2008; Barrington, 2006). Slight differences sometimes arise due to the definition of enrolment; however, variations between different data sets for the core science subjects are within ±2%.

In this analysis we present both the raw enrolment numbers and the subject participation rates, the latter being the proportion of the total Year 12 cohort enrolled in a particular course. While both methods have the advantage of being readily understood, it should be noted that the increasing Year 12 overall cohort numbers can mask underlying trends in individual subjects.

Table 3.3: Highest levels of Year 12 science and advanced mathematics subjects analysed in this paper, by state and territory.

State or Territory	Key Learning Area (KLA)	Name of Highest Level of Subject Included in Analysis in 2011
New South Wales (NSW)	Science	Higher School Certificate (HSC) – 2 unit
	Mathematics (Advanced)	HSC – Extension 2
Queensland (Qld)	Science	Authority Subjects – Year 12
	Mathematics (Advanced)	Authority Mathematics C – Year 12
South Australia (SA) / Northern Territory (NT)	Science	South Australian Certificate of Education (SACE) / NTCE - Stage 2 (20 Credits)
	Mathematics (Advanced)	SACE / NTCE - Stage 2 (20 Credits) Specialist Mathematics
Tasmania (Tas)	Science	Tasmanian Certificate of Education (TCE) – Level 3
	Mathematics (Advanced)	TCE – Level 3 Mathematics Specialised
Victoria (Vic)	Science	Victorian Certificate of Education (VCE) – Unit 4
	Mathematics (Advanced)	VCE – Specialist Mathematics Unit 4
Western Australia (WA)	Science	Western Australian Certificate of Education (WACE) – Unit 3B
	Mathematics (Advanced)	WACE – Mathematics: Specialist Unit 3D
Australian Capital Territory (ACT)	Science	T-Accredited – Major
	Mathematics (Advanced)	T-Accredited – Mathematics Double Major

Science and mathematics subjects are often reported as being gender biased in their enrolments (Fullarton, Walker, Ainley, & Hillman, 2003). In these analyses, the sex ratio is presented as the proportion of female enrolments in a particular course.

Australian Year 12 students can and often do enrol in multiple science courses; however, because of the way enrolments are reported by the states and territories it is not possible to determine reliably the number of students enrolled in multiple courses. A similar issue exists in determining the total enrolment numbers for mathematics as intermediate enrolments often include the advanced enrolment numbers. Consequently an overall participation rate for science or mathematics can neither be accurately determined nor reasonably estimated.

Results of the analysis of the enrolment trends

Overall school participation and retention

Figure 3.1 presents the overall enrolment numbers for Year 8, Year 10 and Year 12 students and retention rate from Year 10 into Year 12 from 1992 to 2012.

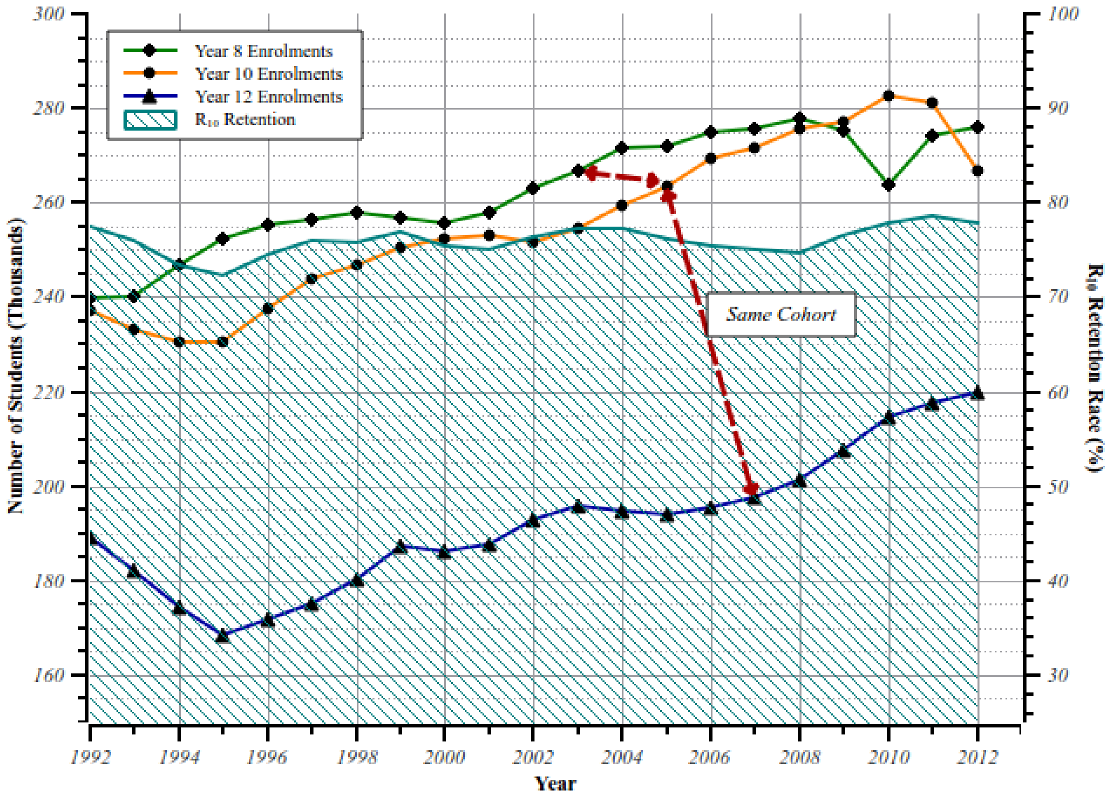

Figure 3.1: Trends in overall school enrolment numbers from 1992 to 2012.

The trends in overall national enrolment numbers (left hand axis) for Year 8, Year 10 and Year 12 have been steadily rising from 1992 to 2012, while the retention rates from Year 10 into Year 12 (right hand axis) have been fairly stable.

Figure 3.1 shows that in general terms the number of students in Year 12 has risen year on year as a consequence of a rising school population in Year 10. The Year 12 data were compiled from total examination candidature from the state and territory qualification authorities. The Year 8 and Year 10 enrolments were compiled from Australian Bureau of Statistics [ABS] data (ABS, 2013). The total number of Year 12 enrolments in 2012 was 219,907 compared with 189,041 in 1992. Throughout most of the period the $R_{10\text{-}12}$ retention rate (the proportion of students retained into Year 12 from the parent Year 10 cohort) remained fairly stable at around 75% (standard deviation 1.4%) before increasing from 2008 onward. This increase in $R_{10\text{-}12}$ retention is most likely either a consequence of the move by all state and territory governments to increase the general school leaving age to 17 years old (Council of Australian Governments (COAG), 2009) or of an increase in overseas students migrating to Australia to complete pre-university studies (Department of Immigration and Citizenship [DIC], 2011).

Most previous studies, including Dekkers and de Laeter (2001), used Year 8 as the base line for retention rates as historically this has been the first common year of secondary school. As can be seen by comparing the Year 8 and Year 10 lines on Figure 3.1, which follow almost identical trends, the R_{8-12} and R_{10-12} retention rates could be used interchangeably until 2008. However, post-2008 we choose to use the R_{10-12} retention rate as Year 10 represents the end of compulsory education in most KLAs and takes into account the swelling of the Year 10 cohort compared to the corresponding Year 8 group.

It is also worth noting the significant dip in student numbers in 2010 (Year 8) and 2012 (Year 10). This is due to a shortfall of around 10,000 students in Western Australia caused by the so-called "half-cohort"; a consequence of an increase to the school starting age by six months in that state in 2001 (Australian Bureau of Statistics [ABS], 2010). This should cause a corresponding dip in the 2014 Year 12 datasets.

Participation rates, enrolments and sex ratios of individual subjects

Figure 3.2 shows changes in participation rates of science and mathematics subjects from 1992 to 2012. It is clear that all the subjects analysed show declines in their individual participation rates except earth sciences, which exhibits marginal growth, and entry mathematics which shows steady growth. The major part of these declines occurred prior to 2002 and the rate of decline has been generally lower in subsequent years. The enrolment trends for individual courses will be discussed in detail in the following sections. For clarity we will discuss changes in participation rates in terms of the total Year 12 cohort, rather than changes within individual courses.

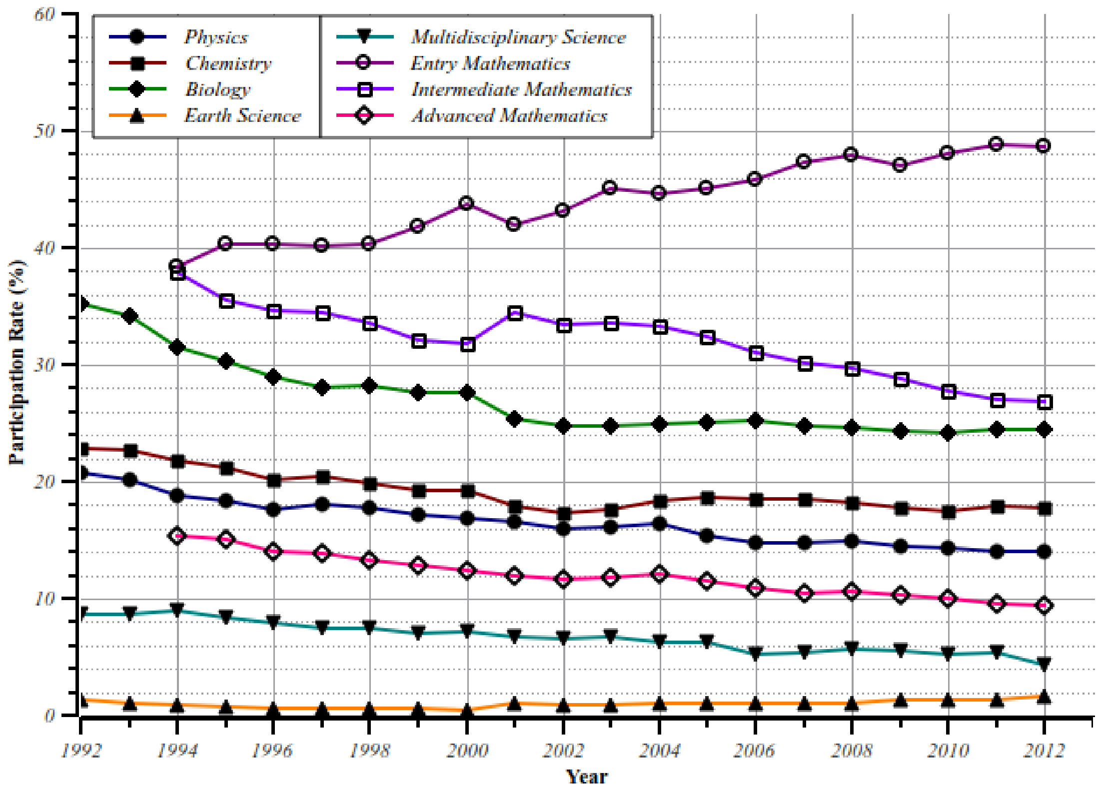

Figure 3.2: The participation rates for science and mathematics subjects as a proportion of the overall year 12 cohort size have been declining over the period 1992 to 2012

Figure 3.3 shows the changes in absolute student numbers for science and mathematics subjects over the same period. As can be seen from this figure, the number of students enrolled in most of these courses declined markedly between 1992 and 1996 before recovering slightly. From 2001 the number of students studying entry mathematics has risen dramatically, the number studying biology, chemistry and earth sciences has risen slightly while the numbers enrolled in physics, advanced mathematics and multidisciplinary science have continued to decline slightly. Intermediate mathematics witnessed an increase in enrolments in 2001 followed by a steady decline.

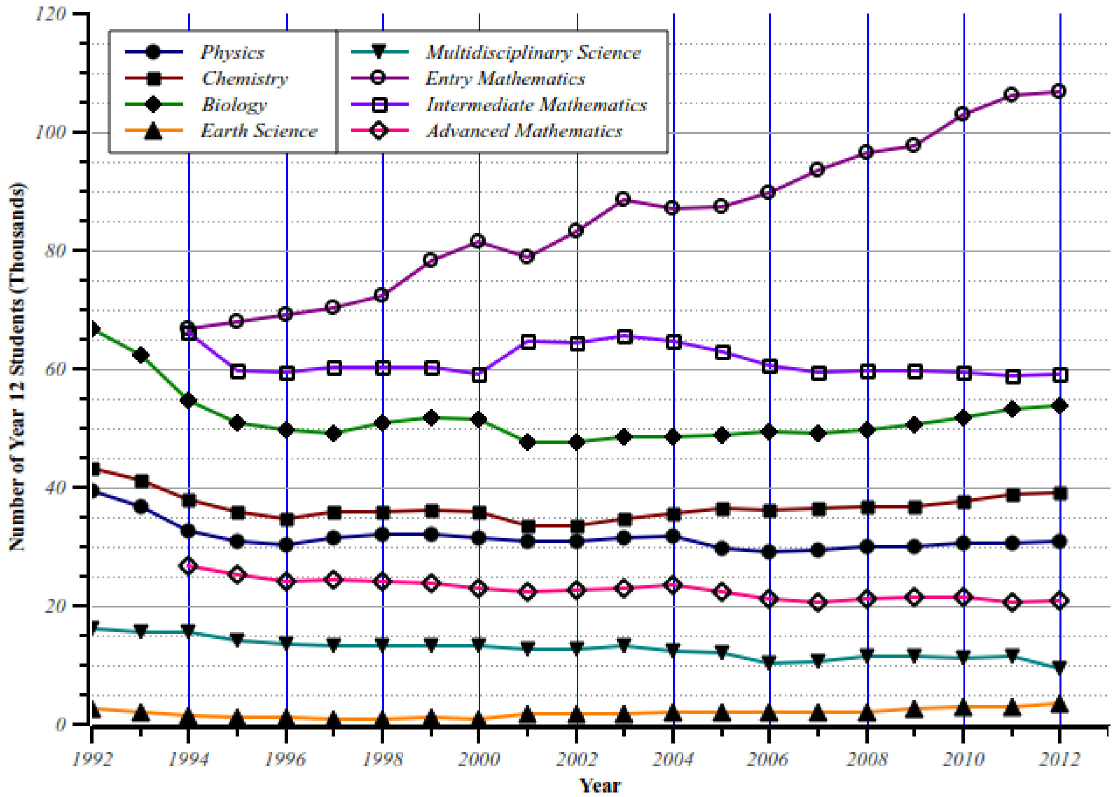

Figure 3.3: The trends in the raw numbers of Year 12 student enrolments in science and mathematics courses, 1992-2012

Figure 3.4 shows the sex balance within each of the subjects displayed as the proportion of female enrolments. It is important to recognise that a sex ratio of 0.50 does not necessarily represent equity; the sex ratio of the cohort as a whole must also be considered. The shaded area on this graph indicates the subjects with a male enrolment bias and the corresponding line indicates equality.

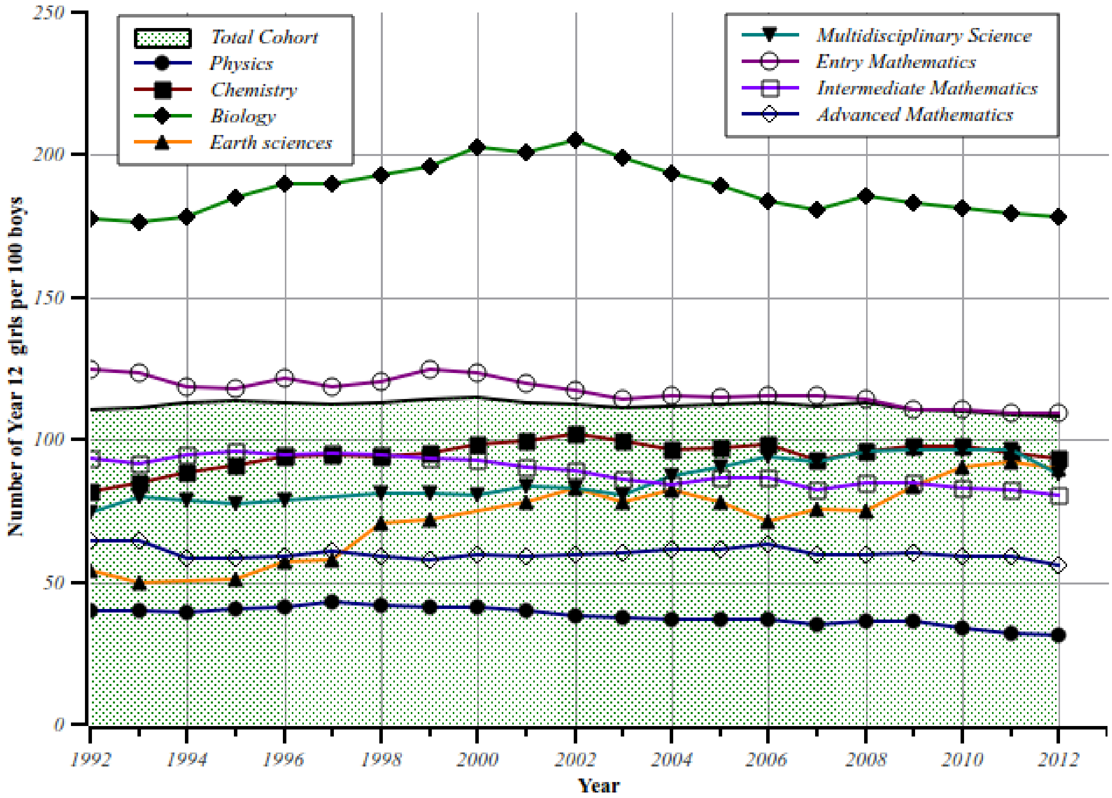

Figure 3.4: Student sex-ratios for science and mathematics courses from 1992 to 2012.

The lines show the number of female students per 100 males enrolled on science and mathematics courses from 1992-2012 with the overall student sex ratio of the Year 12 cohort shown shaded.

This figure shows that from 1992 to 2012, chemistry, multidisciplinary science and earth science have tended towards sex equality while physics, biology and advanced mathematics have retained and in some cases strengthened their respective sex biases. Entry mathematics has been the subject closest to the cohort norm in terms of equality of sexes throughout the study and from 2005 has been almost indistinguishable from the norm.

Trends in physics enrolments

It is apparent from Figure 3.2 that the proportion of Year 12 students studying this subject has steadily declined each year from 21% in 1992 to just 14% in 2012. This is a change of -7 percentage-points compared with the 1992 levels of participation and -2 percentage-points when compared to 2002; i.e. a percentage-change of -33% compared to 1992 or -12% compared to 2002.

In the same period, the number of students enrolled in physics courses declined from around 39,000 in 1992 to around 31,000 in 1996 (Figure 3.3). This level of enrolment remained reasonably stable until 2004 but then fell by a further 2000 students over two years. Since then physics enrolments have been very slowly growing to the present level of 30,877. In relative terms the present number of enrolments represents just 76% of the 1992 numbers.

Figure 3.4 shows that physics has the largest proportion of male students and that this proportion has become steadily larger. In 2012, the sex ratio was 0.25 which equates to approximately three male students for every female.

Trends in chemistry enrolments

Participation rates for chemistry (Figure 3.2) have been in general decline across the period of study from a high of 23% in 1992 to 18% in 2012. Ainley et al. (2008) suggested that chemistry participation may have turned a corner and started to recover, but Figure 3.2 shows that the recovery in participation rates between 2002 and 2005 was short lived and the steady decline has continued. This is a decline of -5 percentage-points on 1992 levels or an increase of +1 percentage-point when compared with 2002; i.e. a percentage-change of -22% compared to 1992 or +2% when compared with 2002.

Figure 3.3 shows that absolute enrolments in chemistry declined steadily by 10,000 students over the period 1992 to 2002 from an initial level of around 43,000. Since this date, enrolments have continued the gradual rise identified by Ainley et al. (2008) and in 2012 reached 39,187 students. The present enrolments account for 90% of the 1992 numbers or a 17% gain on the 2002 figures.

Chemistry exhibits fairly good balance between the sexes with the sex ratio relatively stable around 0.49 since 1995 (Figure 3.4). This equates to around 26 males for every 25 female students.

Trends in biology enrolments

The participation rates for biology (Figure 3.2) from 1992 to 2002 dropped from 35% to around 25% and mirrored the trends in raw enrolments (Figure 3.3). However, since 2002 the participation rates have been relatively stable, only falling to 24.5% by 2012. This is a change of -10 percentage-points compared with 1992 or -0.5 percentage-points with respect to 2002; i.e. a percentage change of -31% compared with 1992 or -1% compared with 2002. This can be accounted for as the increases in raw biology enrolments (Figure 3.3) were only slightly outstripped by the increases in the total Year 12 cohort.

Biology has remained the most popular science subject throughout this period. Enrolments were around 67,000 students in 1992 and declined steadily to approximately 48,000 in 2002 (Figure 3.3). There has since been steady improvement with enrolments reaching 53,802 in 2012. The 2012 enrolment figures represent 81% of the 1992 numbers or a gain of nearly 13% on 2002.

Female students have consistently shown a preference for biology over their male peers throughout the period of study. The sex ratio tended even further towards females reaching a peak of 0.67 in 2004 (Figure 3.4) but has since moved back slightly. In 2012 the sex ratio was 0.65; this indicates that there were around nine females enrolled for every five males.

Trends in earth science enrolments

Participation rates (Figure 3.2) in earth sciences have been reasonably stable from 1992-2012 and follow a very similar pattern to raw enrolment numbers (Figure 3.3). In 1992 earth sciences had a participation rate of 1.3% which fell to a low of 0.5% in 2000 before climbing to a level of 1.6% in 2012.

Throughout the period of study, earth sciences have attracted the fewest enrolments of all the mainstream science courses. However, while enrolments declined from 1992 to less than 1,000 students in 1996, they have been slowly increasing since to 3,470 in 2012 as shown in Figure 3.3.

The apparent changes in sex balance of this group of subjects can be a little misleading as slight variations in enrolment patterns can have visually large effects on the sex ratio due to the small cohort size. Some of this volatility can be explained by the introduction of additional courses in the earth sciences group by a number of states and territories to complement the more traditional geology-like courses. Figure 3.4 shows that earth sciences have been predominately male-biased but post-2006 the sex balance has been trending towards equity. In 2012, the sex ratio of 0.47 represents nine female students for every ten males.

Trends in multidisciplinary science enrolments

Participation rates in the courses comprising the multidisciplinary science category have followed the common trend and have suffered a steady decrease over the period falling from around 9% in 1992 to 4.3% in 2012 (Figure 3.2).

Actual enrolment numbers show a long, slow decline from around 16,000 in 1992 to a low of around 10,000 in 2006 (Figure 3.3). More recently enrolments had begun to appear to recover yet in 2012 they fell to a new low of 9,386. The 2012 enrolments represent 59% of the 1992 or 74% of the 2002 numbers.

Multidisciplinary science shows a slight male bias but from 2005 onward this balance has been tending towards equity. In 2012, there were 22 females per 25 males represented by a sex ratio of 0.47 (Figure 3.4).

Trends in entry mathematics enrolments

As can be seen in Figure 3.2, entry mathematics has followed a very different trend to all the other subjects analysed in this paper. Participation rates have steadily increased from 38% in 1994 to around 49% in 2012. This represents a change of +11 percentage-points on the 1994 levels or +5 percentage-points on the 2002 levels; i.e. a percentage-change of +27% compared with 1994 or +13% compared with 2002.

Figure 3.3 shows that the actual number of students enrolled in entry mathematics has risen from around 67,000 in 1994 to 106,900 in 2012. The rate of increase in enrolments has been fairly steady over the 20 years of the analysis, excepting the significant drop in 2001. This can be accounted for entirely by a drop in the New South Wales enrolments, which coincided with significant syllabus changes and reorganisation in this state. The 2012 enrolment numbers represent an increase of 60% on the 1994 enrolments or 28% compared with 2002.

Entry mathematics has traditionally had a slight female bias. Over the period of these analyses this has tended towards equity and from 2008 the sex ratio has been almost indistinguishable from the Year 12 cohort norm; in 2012 the sex ratio was 0.522 while the cohort norm was 0.520. This equates to eleven females per ten males.

Trends in intermediate mathematics enrolments

Figure 3.2 shows that intermediate mathematics is almost the reverse image of entry mathematics. Participation rates have steadily fallen from 38% in 1994 to 27% in 2012. This is a decline of -11 percentage-points on the 1994 baseline or a decline of -7 percentage-points on 2002 participation rates; i.e. a percentage change -29% compared to 1994 or -11% compared to 2002.

In terms of raw enrolments intermediate mathematics has been remarkably stable showing virtually zero growth over the 20 years of this analysis. 1995 marked the beginning of a six year stretch where the total number of students was around 60,000. In 2001 there was a significant increase to 65,000, which coincides with the syllabus overhauls in NSW and the subsequent increase in state enrolments. From 2003 the total number of enrolments declined to the historic level of around 60,000 by 2007 and in 2012 there were 59,144 enrolments.

Although total enrolments have remained relatively steady, the sex balance of the course has changed slightly. Intermediate mathematics has shown a male bias that has become slightly stronger over time. In 1994 the sex ratio was 0.37 while in 2012 it was 0.35, equating to eight females for every ten males.

Trends in advanced mathematics enrolments

As can be seen in figure 3.2, advanced mathematics has followed a similar trend to physics and to some extent chemistry. Participation rates have steadily declined from around 16% in 1994 to 9% in 2012. This is a change of -7 percentage-points compared with the 1994 participation levels or -3 percentage-points on the 2002 data; i.e. a percentage change of -39% compared to 1994 or -19% compared to 2002.

Figure 3.3 shows that raw enrolment numbers declined from around 27000 in 1994 to a low point of 20600 in 2007. Since this time, enrolments have been relatively static with 20789 enrolments in 2012. This corresponds to 77% of the 1994 levels or 93% of the 2002 data.

The sex balance within advanced mathematics, as shown in Figure 3.4, has been remarkably stable throughout the period at 0.37, representing six female students per ten males. This dropped slightly in 2012 to 0.35 corresponding to 14 female students for every 25 males.

Discussion

At first glance, the National Partnership Agreement on Youth Attainment and Transitions (Council of Australian Governments (COAG), 2009) would suggest that from 2012 onward there should be an increase in the $R_{10\text{-}12}$ retention rate (Figure 3.1), caused by a swelling of Year 12 as students became required to remain in full time education, training or employment until the age of 17. This overall swelling could be expected to comprise students who would have traditionally left school at Year 10 and who may not be academically inclined towards science and mathematics in Year 12. If this change in cohort profile is correct, there should be a corresponding drop in the participation rates for science and mathematics (Figure 3.2). However, we observe neither an increase in retention in 2012 compared to previous years nor any significant change in the rate of decline in subject participation rates excepting multidisciplinary science which is caused by a drop in raw enrolment numbers (Figure 3.3). This apparent anomaly can be traced to the cessation of Multi-Strand Science in Queensland (Qld Studies Authority [QSA], 2013). After one cohort, the change to the school leaving age appears to have had no direct effect on the number of students completing Year 12 with a traditional credential; whether this will change over the next five to ten years remains to be seen.

The sex ratios presented in Figure 3.4 show that some subjects show a definite bias towards one sex or the other. This is particularly clear in physics and advanced mathematics. Discussion of the complex and multi-faceted potential reasons for this bias is beyond the scope of this paper but there is a strong research field exploring the reasons for women leaking from the STEM "pipeline' (e.g., Clark Blickenstaff, 2005). As shown in Figure 3.4, most subjects have remained fairly consistent in their sex balance since 2002, except for biology and physics which have shown changes towards proportionally fewer females and earth science and multidisciplinary science which have shown changes towards proportionally more females. Figure 3.3 suggests that in the case of biology this change has been brought about by an increasing number of males electing to do the subject, and conversely in earth science an increasing number of females choosing to the course. However, examining multidisciplinary science leads to the conclusion that fewer students overall, and males in particular, are choosing this subject. A similar story can be seen in the physics data; students in 2012 are overall less likely to study physics than in 2002 and female students are even less likely to do so than their female counterparts in earlier cohorts. The factors lying behind these trends are likely to be a combination of personal relevance, interest, difficulty and cultural characteristics (Lyons, 2006), but the granularity of the data analysed here is too coarse to allow this to be examined further.

A potential explanation for the falling subject participation rates is that students who previously may have enrolled in two or more science courses are now studying only one (Calderon, Dobson, & Wentworth, 2000; Lyons & Quinn, 2010) due to the breadth of choice currently available. In 2012 the New South Wales Board of Studies (NSWBoS) offered examinations in 124 different courses and levels (NSW Board of Studies [NSWBoS], 2012). If this explanation is correct, then while individual subject trends may show continuing declines, the overall health of science, as measured by the number of students with some exposure to science at the upper secondary level, may still be satisfactory. This hypothesis is interesting yet cannot be easily examined using the available data as combinations of subjects are not published by the various states and territories. The Longitudinal Surveys of Australian Youth (LSAY) reports issued by National Centre for Vocational Education Research (NCVER), formerly issued by the Australian Council for Educational Research (ACER), offer an opportunity to examine this further (Fullarton et al., 2003) yet the demographic profile of the sample remaining in LSAY by Year 12 is not a perfect match for the Year 12 cohort as a whole. Further analysis is required in this area if the effects of combinations of subjects on overall participation rates are to be understood.

As is evident in Figure 3.2, there is symmetry between the participation rate trends of entry and intermediate mathematics; the mean participation rate of these two courses has remained fairly constant at 38±1% over the entire period from 1994 to 2012 This suggests that the growth in entry mathematics is not a result of an increased proportion of Year 12 students studying mathematics, but is a consequence of students selecting a non-calculus course (entry) in preference to a calculus-based course. It can also be seen that both entry and intermediate mathematics courses have become slightly more male-biased over time. Combining this with the declines seen in advanced mathematics could suggest that students of both sexes are abandoning advanced mathematics in favour of intermediate, while the changes from intermediate mathematics see male students selecting entry mathematics while females elect no mathematics. This summary is necessarily coarse due to the granularity of the data but supports the findings of Mack and Walsh (2013) in relation to girls in NSW and needs further investigation at the national level.

Chinnappan, Dinham, Herrington and Scott (2008) suggested that the declines in advanced mathematics then could be due to many reasons including a lack of potential career information and a lack of understanding of the role of mathematics in science. A study by McPhan, Morony, Pegg, Cooksey, and Lynch (2008) suggested that the blockers towards student enrolments in mathematics are unsurprisingly similar to those in the sciences namely; self-perception of ability, perceptions of difficulty and usefulness, previous achievement, and interest and liking of mathematics. The very close mirroring of the trends in physics and advanced mathematics seen in Figure 3.2 are suggestive of common causation. Arguably, students may be assessing the utility value of Year 12 courses and then selecting courses at a level appropriate to their immediate needs (e.g., university entrance scores) rather than their future aspirations. The selection of courses is further complicated by the tertiary course information made available to students through the Universities Admissions Centre (UAC). The entries in the 2013-14 UAC (NSW/ACT) guide for example often make reference to Mathematics as *assumed knowledge* yet do not state the level of mathematical expertise required by the student in order to succeed in a particular course. Limited mathematical background results in students struggling to make adequate progress once they reach university (Brown, 2009).

Conclusions and Recommendations

Participation in science and mathematics courses by Australian Year 12 students, with the lone exception of entry mathematics, has been declining in real terms for the greater part of the past two decades and continued to do so in 2012. The magnitude of this rate of decline has been less in recent years than prior to 2002 but continues steadily. It is important that these enrolment trends continue to be monitored and updated regularly so that accurate and current documentation of the trends is maintained.

While the declining participation rates in advanced and intermediate mathematics are relatively straightforward to track, it is not a simple task to determine where these students are going. Due to the tiered nature of mathematics education it could be assumed that the advanced mathematics students are simply dropping a level to intermediate mathematics. Yet this is easier to hypothesise than understand and is made particularly difficult by the abundance of mathematics courses available across the country that are not easily comparable. In order to understand the true state of school mathematics, it is essential that the states and territories agree on the definition of the content of each level of the mathematics offerings so that overall enrolment numbers for each of these category can be distilled and the overall health of the subject be discerned.

The available Year 12 curriculum has significantly broadened throughout the period covered by this analysis creating an increased range of subjects from which students can choose. There is some suggestion that responses to systemic changes such as the transition away from prerequisite courses by universities, a reduction in the minimum number of required subjects in some states and territories, and the clever choice of courses to maximise a student's tertiary admissions rank may have combined to encourage students, who may be considering a career in science or engineering, to select courses primarily on the basis of immediate interest rather than as a foundations for future needs. The analyses presented in this article can neither support nor refute this argument and a more extensive analysis across a wider selection of subjects is needed to investigate this further.

Ultimately, these analyses show that participation in post-compulsory school science and tertiary-enabling mathematics continues to decline. Is this a crisis? We hesitate to describe it as such, since the continuing declines are very gradual. However, should government, industry and the educational sector be alarmed by these trends? Yes. If school STEM is to continue to be a cornerstone of creating scientifically aware and literate citizens then it is important to understand why students are electing not to continue the study of school science. Examining enrolment data can only reveal the general trends in this regard. Further investigation with the students in compulsory science education is required to understand why, when and how they make the decision to turn away from science courses and to also understand what they elect to study to replace them.

3.4 Statement of authors' contribution

We, the PhD candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in this thesis and they have accepted the candidate's contribution as indicated in the Statement of Originality.

	Author's Name	**% of contribution**
Candidate	JohnPaul Kennedy	80
Other Authors	Associate Professor Terry Lyons	10
	Dr Frances Quinn	10

[redacted]

JohnPaul Kennedy
(Candidate)

25th September 2018

[redacted]

Dr Frances Quinn
(Principal Supervisor)

25th September 2018

3.5 Statement of originality

We, the PhD candidate and the candidate's Principal Supervisor, certify that the following text, figures and diagrams are the candidate's original work.

Type of Work	Page Number/s
Figure 3.1	52
Figure 3.2	54
Figure 3.3	55
Figure 3.4	56

[redacted]
JohnPaul Kennedy
(Candidate)

25th September 2018

[redacted]
Dr Frances Quinn
(Principal Supervisor)

25th September 2018

Chapter 4: Australian enrolment trends in Technology and Engineering: Putting the T and E back into School STEM

4.1 Introduction

The two research themes established in Chapter 1 (p. 5) focussed this thesis in the area of STEM subjects in Australian high-schools. In Chapter 3.3 I focussed on the declining participation patterns in science and mathematics. This chapter aims to complete the picture by reporting the results of similar analyses within the technologies and engineering domains. This chapter is unique from a research perspective in that it presents enrolment trends from all five course areas—as identified by the Australian Curriculum, Assessment and Reporting Authority—of the technologies domain for the first time. An understanding of this area, and its relationship to the more well documented science and mathematics domains, is essential in answering research questions RQ2, RQ3, RQ4 and RQ5.

To maintain analytical comparability with the data presented in Chapter 3.3 an identical methodology was adopted to that outlined previously. There were a number of confounding factors, additional to those identified in regards to science and mathematics, that influenced the collection of this data. The most significant of these were the wide range of naming conventions used by the various state and territory bodies as well as the rise in the number of courses offered to school students by Vocational Education and Training (VET) providers—who themselves operate outside of, and parallel with, the many school systems in Australia. The summary tables of these compiled data are presented in Appendix A to this thesis.

This article first places the question of technologies and engineering participation into the larger context of general school STEM participation by reviewing relevant literature related to enrolments, student participation and educational policy over a period of two decades. As part of this I argue that even the term STEM has not been applied consistently and clearly over the period of study and in turn this has at times led to a level of confusion within educational and governmental circles. I also argue that the T in STEM has at times become synonymous with computing, i.e. *information* technology, adding to the confusion surrounding participation in this domain. For the purposes of this thesis, I have resolved this entanglement of terminology by considering technologies and engineering to be two complementary aspects of the same educational domain. This has led to the adoption of the five course areas outlined in Table 4.1.

The analysed data are then presented and considered in the context of the overall *crisis* in STEM. Significantly, the presented trends show slow but steady growth in most course areas with the notable exception of digital technologies. In RQ2 I ask, "What is the nature of the participation trends in the other STEM fields of technology and engineering [compared to science and mathematics]?", and the data presented in this chapter are crucial in addressing this. Comparing the data presented in Chapter 3.3 with the data presented in this chapter will ultimately allow the formulation of answers to RQ3, RQ4 and RQ5.

4.2 Journal Article 2

This article is reprinted by permission from Springer Nature: International Journal of Technology and Design Education (Australian enrolment trends in technology and engineering: putting the T and E back into school STEM, Kennedy, J., Quinn, F., & Lyons, T. 2017), © 2017 (doi:10.1007/s10798-016-9394-8 IJTDE)

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Australian enrolment trends in Technology and Engineering: Putting the T and E back into School STEM.

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There has been much political and educational focus on Science, Technology, Engineering and Mathematics (STEM) in Australian schools in recent years and while there has been significant research examining science and mathematics enrolments in senior high school, little is known about the corresponding trends in Technologies and engineering. Understanding these subjects is essential for educators and policy-makers alike if Australians are to embrace the challenges of an innovation economy. We have collected raw enrolment data from each of the Australian state and territory education departments from 1992 to 2014 and analysed this across five Technology and Engineering subject areas. We also consider some of the relationships between these subject areas and other areas of the STEM equation. The results of these analyses are discussed in terms of absolute enrolments, participation rates and sex balance. We have found that the total number of students in Year 12 increased year on year and that this growth is echoed, to a lesser extent, in the participation rates for design technology, food technology and engineering. Digital Technologies however, grew rapidly until 2000, after which time it has been in steady decline. We identify that while the trends mostly show growth, there is a concerning male bias to many of these subject areas. We suggest that the broadening of the upper high school curriculum, confusion surrounding vocational training enrolments, and gamesmanship of the university entrance system, may be contributing to the limited growth observed. Finally, we identify a number of important areas for further research in this key learning area.

Introduction

The status of Science, Technology, Engineering and Mathematics (STEM) in Australia has been the focus of much political discussion and many education initiatives in recent times. STEM is being lauded as the driving force of the Australian economy over the next 20 years (Commonwealth of Australia, 2015b) and a National STEM School Education Strategy (Education Council, 2015) has recently been established. Much has therefore been made of the need to produce more STEM-proficient students in Australian high schools. Indicative of the activity around STEM education, one recent national survey found over 250 different extra-curricular school STEM programs available around the country (Office of the Chief Scientist, 2016), while another survey of Australian employers indicated that 45% expected their demand for STEM skills to grow by 2020 (Deloitte Access Economics, 2014).

In the current national discussion surrounding STEM, the term itself tends to be used in two different contexts. Those more familiar with the origins of the STEM movement understand it as an integrated, interdisciplinary approach to student learning coupled with real-world applications and contexts (Lederman & Lederman, 2013; Tsupros, Kohler, & Hallinen, 2009). The integrated conception of STEM, while becoming more popular, is still relatively rare in Australian schools. By contrast, as the term STEM has become more common in political and public discourse there has been a greater tendency for it to be used as a convenient catch-all for the four fields, individually or collectively, and across the school, university and industry domains.

When the term STEM is used casually in relation to schools, engineering and technology are often overlooked; the former because it is not commonly taught as a stand-alone subject, and the latter because the 'Technologies' key learning area (KLA) encompasses such a wide range of subjects from software design to food technology. Science and mathematics tend to take centre-stage in research focus and much public commentary, while engineering and technology wait in the wings. This is likewise the case with research on participation in school subjects (e.g., Barrington & Brown, 2005; Dekkers & de Laeter, 2001; Kennedy, Lyons, & Quinn, 2014), most likely because Technologies subjects are classified variously in different states and territories, and consequently national enrolment trends are very difficult to track and collate.

Two reports from the Australian Council for Educational Research (ACER) provide some enrolment data up to 2007. Fullarton, Walker, Ainley and Hillman (2003) identified that in 2001 computer studies had the highest share of Technologies enrolments, followed by food science and technical studies. Ainley, Kos and Nicholas (2008) identified relatively stable Australia-wide participation rates across most technology subjects from 1996 to 2007 with the notable exception of computer studies—where national enrolments peaked at 25% of the Year 12 cohort in 2001, then fell rapidly towards 14.5% in 2007. Their report also noted that food and home science enrolments increased from almost 5% to 8% over the period of their analysis. Since these reports however, little has been done to monitor or explore further changes. Engineers Australia's annual Statistical Overview

(Kaspura, 2015) has as one of its foci the transition of students from schools to university courses in engineering. While discussing trends in school mathematics and science, this engineering-focussed report does not focus specifically on trends in school Technologies subjects.

On the international stage digital technologies (variously described as computer science, ICT, and computing) has garnered much of the attention within the Technologies KLA. Most published research focuses on the university sector, where there are indications of declining enrolments and high attrition in some contexts. For example, Brinda, Hermann and Schulte (2009) noted that only 7.6% of university entrants elected to major in computer science and over a third of these failed to complete their courses while Vegso (2008) reported decreased enrolments during the early 2000s of as high as 60% in computer science in US colleges. The few studies reporting trends in upper secondary schools similarly point to concerns about enrolments. For example, the low levels of enrolments in digital technology courses in New Zealand in the mid 2000s (Bell, Andreae, & Lambert, 2010) resulted in the adoption of Digital Technology Guidelines to formally define a computer science curriculum in schools (Ministry of Education, 2010). In a US study, Carter (2006) attributed declines in tertiary computer science primarily to students having an inaccurate (or no) perception of what computer science entails, because of an inadequate exposure to the field in high schools.

Hence, with the implementation of the *Australian Curriculum: Technologies* on the horizon, it is important to update our knowledge of the enrolment patterns in Technologies and establish an enrolment benchmark at this point. It is also significant that we take this snapshot now at this stage of the school STEM movement, as the school approach to STEM often uses technological and engineering contexts to provide real-world examples and applications for the scientific and mathematical knowledge and thinking valued by employers and society. Furthermore, the analyses of previous trends are now nearly a decade old and it is crucial that effective policy, planning and initiatives are informed by the most accurate and up to date information. In particular, if the adoption of the National STEM School Education Strategy (Education Council, 2015) is to be effective then it is essential that the current educational landscape be well mapped. By putting the ‘T and E’ back into the STEM enrolment picture, stakeholders can begin to see similar and contrasting characteristics and trends with mathematics and science enrolments.

This paper provides an analysis of Australian senior high school (Years 11 and 12) Technologies and engineering enrolment trends over the last two decades. The raw data were collected from each of the eight state and territory departments of education, catalogued and collated to create the most up-to-date national Year 12 enrolment database available. The trends in the participation rates are discussed here both in terms of individual subject areas and in the wider context of the Technologies KLA. We show that while there are some areas of enrolment growth, there are also some areas of decline. Taking a STEM perspective, we also report on our exploration of patterns with respect to science and mathematics enrolments to identify any apparent relationships for future investigation. To fully understand the causes of and relationships between these trends requires a deeper analysis than can be offered in this paper; however some general conclusions and recommendations are offered here.

Background

In the Australian education system the majority of students commence high school (Years 7-12) at age 12 or 13, and are legally required to remain in compulsory education, employment or training until the age of 17. In practice this requirement has resulted in a majority of students (85.6% of females and 77.4% of males) completing Year 12 studies (Australian Bureau of Statistics, 2015). The federally administered Australian Curriculum, Assessment and Reporting Authority (ACARA) has responsibility for the production and dissemination of the Foundation (also known as Kindergarten) to Year 10 curriculum which is then interpreted and implemented by the state and territory education departments. School curricula and exit qualifications are the responsibility of the eight state and territory governments and variously consist of four to six subjects, usually including English as a mandated course. In 2014, 1.1% of students complete the externally administered International Baccalaureate Diploma Programme as an alternative to the state based leaving qualification. Within this complex curriculum model, the Technologies KLA is a mandatory component for all students until the end of Year 8 when it takes on many elective forms including specific engineering courses in some jurisdictions.

One of the issues to be considered in understanding enrolment trends is the classification used to refer to the broad range of course options available across the Technologies KLA and across the various educational jurisdictions. ACARA defines two distinct subjects within the Technologies curriculum: F-10—digital Technologies and design and technology—each with a number of learning contexts (Australian Curriculum and Assessment Reporting Authority, 2015). In Years 11 and 12 these subjects are built upon by the states and territories into a wide range of separate courses. Following consultation with ACARA's Technologies Project Officer (J. King, personal communication, 12 July 2015) we have elected to include five course areas within this analysis. Although there are many specific courses, these five *course areas* are available to students, in approximately comparable form, across all eight jurisdictions (except for food and fibre production in Tasmania and The Australian Capital Territory), and therefore can be used to represent the breadth of the KLA in the final years of school. Over the last 20 years however, the availability, nomenclature and content of the Year 11 and 12 courses offered by the different states and territories have changed significantly. Table 4.1 shows the courses (as offered in 2014) included in each course area. We note that Ainley et al. (2008) included hospitality studies as a separate grouping, yet we have excluded it from our analyses due to its offering in many states and territories only as a vocational learning area partly outside the formal control of schools. We have also decided to include agricultural science (in the food and fibre production subject area) and computer science (in the digital technology subject area) in our analyses in keeping with ACARA recommendations, even though some states and territories regard these courses as part of the science KLA in Years 11 and 12. Since around 2001, Vocational Education and Training (VET) courses have also been recognised as equivalent to school-based courses as part of a student's exit qualification. Many of these VET courses fall into the subject areas of the Technologies KLA, however, the naming and classification of these courses has varied so much across the period of research, and appears so inconsistent between jurisdictions, that these students cannot be reliably included in the following analyses.

Table 4.1: Offered Year 11 and 12 courses across the Technologies key learning area by subject areas and jurisdiction as at 2014.

Jurisdiction	Australian Curriculum: Technologies F-10				Engineering (*Engineering thinking focus*)
	Digital Technology (*Computer programming and use foci*)	**Design Technology** (*Design and use of technology foci*)			
		Design Technology	**Food Technology**	**Food and Fibre Production**	
New South Wales (HSC 2 Unit)	• Information processes and technology • Software design and development	• Design and Technology • Industrial Technology • Textiles and Design	• Food Technology	• Agriculture	• Engineering Studies
Victoria (VCE Unit 4)	• Information technology – IT applications • Information technology – software development	• Product Design and Technology	• Food and Technology	• Agricultural and Horticultural Studies	• Systems Engineering
Queensland (Authority Subject)	• Information processing and technology • Information technology systems	• Technology Studies • Graphics	• Home Economics	• Agricultural Science	• Engineering Technology • Aerospace Studies
South Australia / Northern Territory (Stage 2: 20 Credits)	• Information technology • Information processing and publishing	• Design and Technology – Communication Products • Design and Technology – Material Products	• Food and Hospitality • Nutrition	• Agriculture and Horticulture	• Design and Technology – Systems and Control Products
Australian Capital Territory (T-Accredited)	• Information technology T	• Design and Technology T • Textiles and Fashion T • Design and Graphics T	• Food Science and management T	• No equivalent	• Engineering Studies T

Jurisdiction	Australian Curriculum: Technologies F-10				Engineering *(Engineering thinking focus)*
	Digital Technology *(Computer programming and use foci)*	**Design Technology** *(Design and use of technology foci)*			
		Design Technology	**Food Technology**	**Food and Fibre Production**	
Tasmania (Level 3)	• Computer science 3 • Information systems and digital Technologies 3	• Electronics 3 • Computer graphics and design 3 • Housing and design 3 • Technical graphics 3	• Food and Nutrition 3	• No equivalent	• No equivalent
Western Australia (Stage 3)	• Computer Science • Applied information technology	• Design • Materials design and technology	• Food Science and Technology	• Animal Production Systems.	• Engineering Studies • Aviation

Methods

Data Collection

Each year the state and territory curriculum authorities collect raw enrolment numbers for every Year 12 course, in various forms. The national statistics presented here are manually compiled from these individual raw data sets supplemented with additional publicly available data from other organisations (e.g. International Baccalaureate Organisation). As outlined in Kennedy et al. (2014), the year 1992 was selected as a suitable reference-level for science enrolments as previous work (Dekkers & de Laeter, 2001) had shown this as the year in which Year 10 to 12 retention rates began to stabilise at around 75%. These analyses of Technologies enrolments complement our recent analyses of science and mathematics enrolments (Kennedy et al., 2014) and share the same reference year.

Definitions and Constraints

In order to allow valid comparisons to be made between states and over time, only enrolments in the highest level Year 12 courses available in each subject area (see Table 4.1) are included in this analysis. Although this data collection context is slightly different to that of Ainley et al. (2008), there is general agreement between the results presented here and this earlier work. Additionally, this is the same context adopted in our earlier work (Kennedy et al., 2014) allowing for the direct comparison of these enrolments with those of the Science and Mathematics KLAs.

Throughout this paper we have used the term enrolment to mean students who have enrolled in a school in Australia in their final year of education and have been presented for matriculation to their state or territory education body. Enrolment does not necessarily refer to successful completion of the course.

In the individual analyses below, we have presented both the raw enrolment numbers and the course area participation rates—the proportion of the total Year 12 cohort enrolled in the courses of a particular Technologies KLA course area. While both approaches have the advantage of being readily understood, the increasing total numbers of Year 12 students can mask underlying trends in individual course areas and so we recommend the use of participation rates for comparison purposes.

STEM courses are frequently reported as being generally biased in favour of enrolment by male students (e.g., Clark Blickenstaff, 2005; Hill, Corbett, & St Rose, 2010). To investigate this aspect, the female-male balance of the different course area cohorts is presented below as the number of female students per 100 males enrolled in a particular course. This measure will be referred to as the sex ratio.

Australian Year 12 students are generally unconstrained by the number of courses in which they can enrol in the Technologies KLA. Fullarton et al. (2003) identified that few students take more than one course in the Digital Technologies subject area yet they found it to be a little more common for a student to undertake more than one course from the design and technology subject area. However, due to the unavailability of published, individual level data, it is not possible to reliably determine the number of students enrolled in multiple courses. Consequently any attempt to determine the overall participation rate for the Technologies KLA will always be an over-estimation, and we are not exploring participation in the Technologies KLA overall in this paper.

In order to identify any apparent relationships between courses both within the Technologies KLA and with the wider Science and Mathematics KLAs a series of graphical correlation analyses were performed using the *R* statistical environment (R Core Team, 2014). The *pairs.panels* function from the *Psych* library (Revelle, 2014) was used to produce Scatter Plot Matrices (SPLOM) of the pair-wise course participation rates (Fig. 4.5 and Fig. 4.6). Course areas are plotted on the diagonal with pair-wise scatterplots, linear regression lines and 95% confidence ellipses below the diagonal. The pair-wise correlation coefficients (r) are printed above the diagonal. In order to determine if a particular pair-wise trend is both statistically significant and statistically meaningful (Bryhn & Dimberg, 2011), a two-tailed t-statistic was calculated using the Pearson correlation coefficient and the number of samples according to the method outlined by Lowry (2016). This was used to assess each pair-wise correlation against the null hypothesis (H_0) that the two retention rates are not dependent on each other. A p-value was then determined using the Student's t-distribution with the degrees of freedom being determined by the number of data-pairs minus two. Bryhn and Dimberg (2011) argue that a trend should be considered statistically meaningful if both the coefficient of determination (r^2) is greater than 0.65 and the trend is statistically significant to at least the 95% confidence level.

However, it is important to recognise that a statistically meaningful pair-wise correlation between two course areas does not by itself necessarily indicate the presence of common factors. The course area participation rate data are in reality time-series data which could reasonably be expected to show some level of inter-correlation simply as a result of the time trend itself. An additional indicator of the existence of common exogenous variables affecting two or more course areas would be a statistically meaningful relationship between the course area participation rates after being detrended; that is after the time based growth described by the linear regression line is removed leaving only the random effects that cannot be attributed to time. If both course area participation rates vary randomly together and in-phase, that is, if there is a statistically meaningful positive correlation between their residuals, then this may be an indication of the existence of a common underlying exogenous variable(s). If the correlation between the residuals is a statistically meaningful negative correlation then this may be an indication of the existence of a causal relationship between the course areas, although the direction would be indeterminate from the simple model.

Results and discussion of enrolment trend analyses

Overall school participation and retention

Figure 4.1 presents the overall enrolment numbers for Year 10 and Year 12 students and the retention rate from Year 10 into Year 12 from 1992 to 2014. The Year 12 data are a result of total examination candidature statistics and the Year 10 data are based on Australian Bureau of Statistics data (Australian Bureau of Statistics, 2015). In general terms, Figure 4.1 shows that the total number of Year 12 students has risen year on year in response to a growing Year 10 population. The $R_{10\text{-}12}$ retention rate (the proportion of students retained into Year 12 from the parent Year 10 cohort) has risen steadily since 2008 from its historical level of around 75% to the 2014 level of 81%. The corresponding $R_{8\text{-}10}$ retention rates (not shown: the proportion of students retained into Year 10 from the parent Year 8 cohort) have been slightly in excess of 100% since 2008 (102% in 2014) suggesting that this increase in $R_{10\text{-}12}$ retention is likely a consequence of both the rising of the general school leaving age to 17 years old (Council of Australian Governments (COAG), 2009) and of immigration.

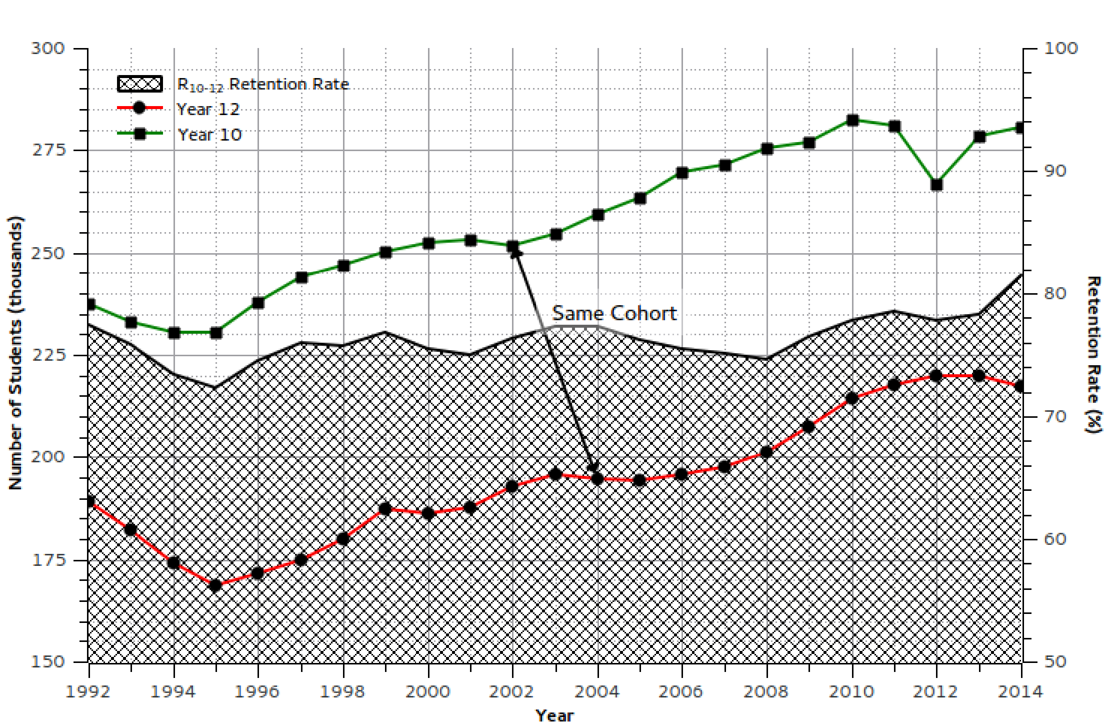

Figure 4.1. Overall national enrolment numbers (left hand axis) for Year 10 and Year 12 with retention rate (right hand axis) from 1992 to 2014.

As we noted in Kennedy et al. (2014) the significant dips in student numbers in 2012 (Year 10) and 2014 (Year 12) are due to the so-called "half-cohort" in Western Australia; a consequence of an increase to the school starting age by six months in that state in 2001(Australian Bureau of Statistics [ABS], 2010).

Participation, enrolments and sex ratios of individual subjects

Figure 4.2 shows the changes in the participation rates across the course areas of the Technologies KLA from 1992 to 2014.

It is clear that while most Technologies course areas show very slight growth since 2000, digital Technologies have suffered significant declines. This is the inverse of the pre-2000 pattern, where all areas were steady or in slow decline except for digital Technologies, which were on the rise. Significantly, all of these course areas account for a very small proportion of Year 12 enrolments with design technology (10.9% in 2014) being the largest contributor. From a STEM perspective, it is interesting to note that this participation rate is reasonably comparable to the participation rate reported for advanced mathematics (9.5% in 2012) reported by Kennedy et al., (2014).

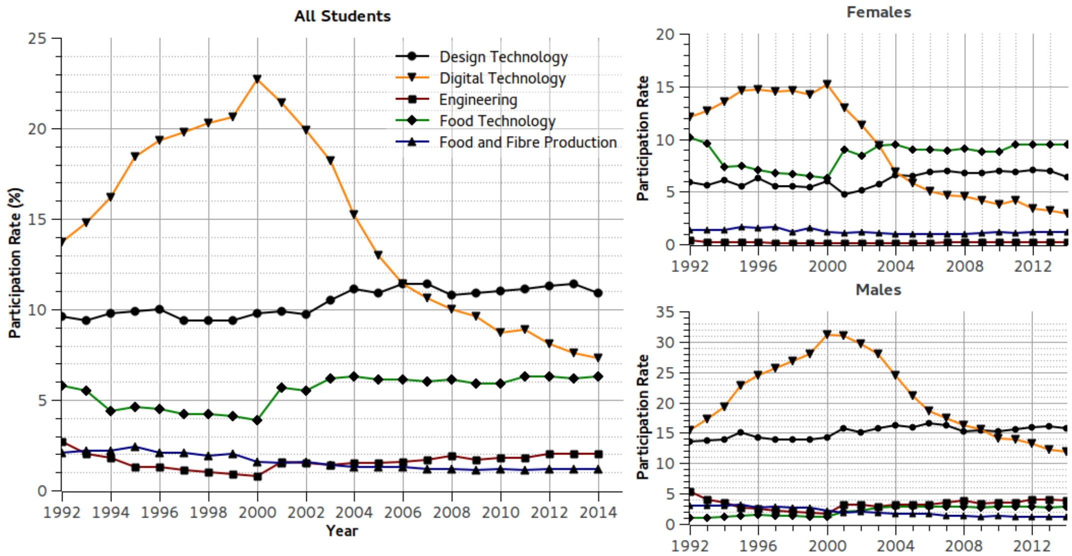

Figure 4.2. Overall participation rates (left) for subject areas in the technologies key learning area, 1992-2014 and broken down by student sex (right).

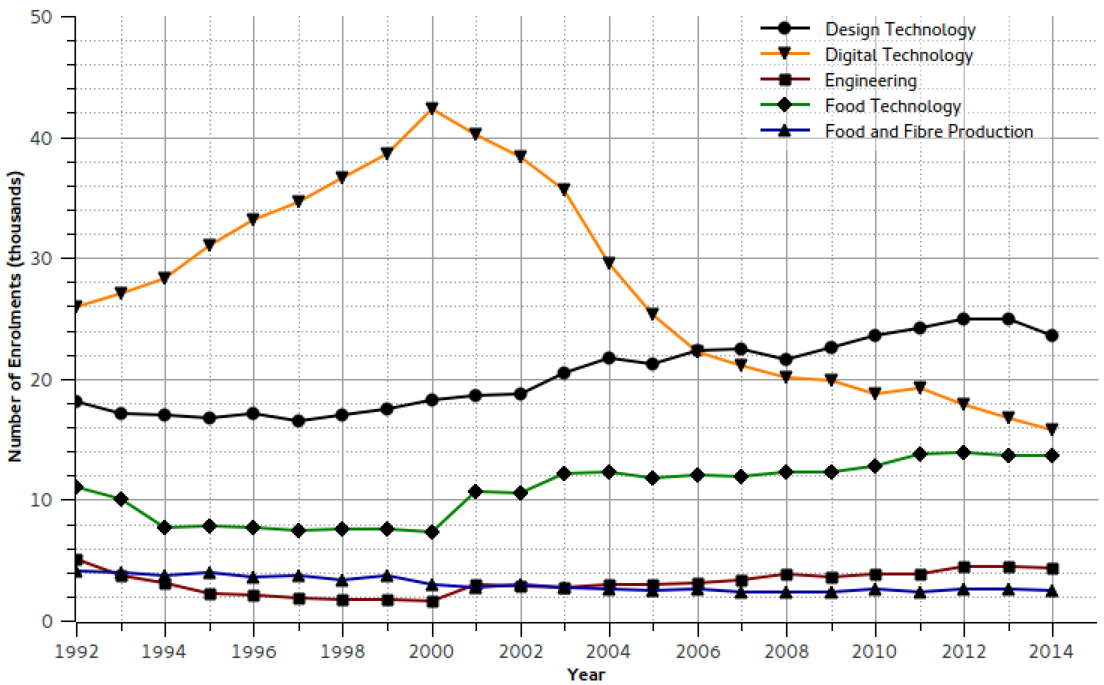

Figure 4.3. Student enrolment numbers for subject areas in the technologies key learning area, 1992-2014

Figure 4.3 shows the changes in absolute student numbers for Technologies course areas over the same period. As can be seen in this figure, the number of students enrolled in most of these course areas has risen steadily between 1992 and 2014 excepting digital

Technologies which witnessed plummeting enrolments post 2000, and food and fibre production where enrolments have declined very slowly since 2000.

Figure 4.4 shows the sex ratio within each of the course areas displayed as the number of female students per 100 males. Figure 4 (lower) shows the same data but focussed on those subjects with a sex ratio less than 150 per 100. It is important to recognise that a sex ratio of 100 does not necessarily represent equity as the sex ratio of the cohort as a whole, which tends to be slightly female biased, must also be considered. The shaded area on this graph indicates the subjects with a male enrolment bias and the corresponding boundary line indicates equality.

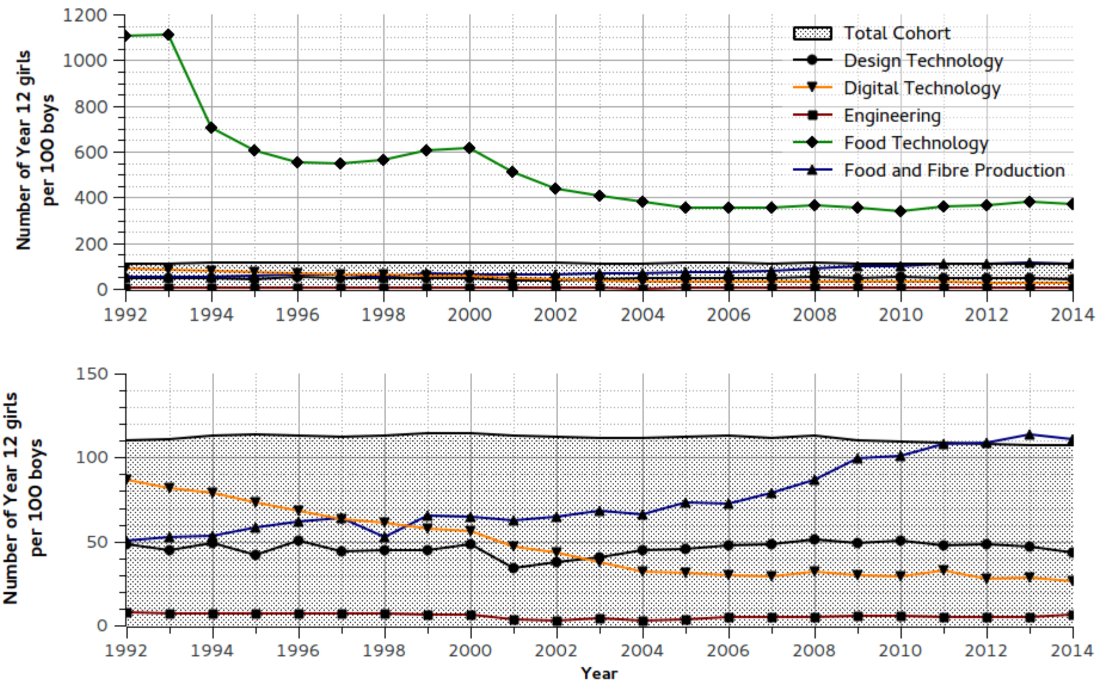

Figure 4.4. Student sex ratios for the subjects in the technologies subject area.

The lines show the number of female students per 100 males within each technologies subject area from 1992-2014. Showing all subject areas (upper) and truncated to male-biased subject areas (lower). The shaded region indicates cohort-parity between the sexes

This figure shows that over the period 1992 to 2014, food and fibre production has tended towards sex equality, although this is possibly overemphasised by the small enrolment numbers, while all other areas have retained or strengthened their respective traditional sex biases.

Trends in design technology enrolments

The design technology course area incorporates a wide range of school-based courses with a strong design element (Table 4.1). As identified by Fullerton et al. (2003), it is likely that some of the enrolments in this course area can be attributed to the same student and so the following participation is likely to be a slight overestimation. It is apparent from Figure 4.2 that the proportion of Year 12 students electing to study this course area remained steady from 1992 to 2000 at around 9.6% before rising to around 11.1% by 2005. Participation has again been reasonably steady since then and was 10.9% of Year 12 students in 2014.

In the same period, the number of students enrolled in design technology courses rose from around 18,000 in 1992 to around 25,000 in 2013 (Fig. 4.3). This level of enrolment has dropped slightly to around 23,500 in 2014 but there is no evidence to suggest this is the beginning of any long term decline. In relative terms the present number of enrolments represents 130% of the 1992 numbers.

Figure 4.4 shows that design Technologies has consistently been a male dominated course group and the sex ratio has not changed significantly over the period of analysis. In 2014, the sex ratio was 44 females per 100 males.

Trends in digital technology enrolments

Participation rates for courses in the digital technology course area demonstrated a significant increase in enrolments throughout the 1990s (Fig. 4.2). Following a peak of 23% in 2000, participation rates have declined markedly to the current level of just 7% in 2014. This current level represents 47% of the 1992 levels or one third of the peak level. Interestingly, the declines observed in the national data are only seen in the records of three jurisdictions—New South Wales (NSW), Victoria and the Australian Capital Territory (ACT)—while other areas have recorded slight growth or static enrolments. Together these three jurisdictions account for around 60% of the total Year 12 cohort numbers, thus explaining the size of the drop seen in the national data post 2000.

Figure 4.3 shows that absolute enrolment numbers in digital Technologies increased steadily from 26,000 to 42,000 in 2000 before falling rapidly to just 15,000 in 2014. The sex balance in digital Technologies has become steadily more male biased over time (Fig. 4.4) changing from 87 females per 100 males in 1992 to just 26 females per 100 males in 2014. This emphasises the decrease in female participation in digital

Technologies where just 2.9% of the female Year 12 cohort, just 3,300 students nationwide, studied this course area in 2014; this is one fifth of the peak female participation rate of 15,000 students recorded in the year 2000.

Trends in engineering enrolments

Engineering has had a consistently low participation rate across the whole period of analysis. Participation rates for engineering courses (Fig. 4.2) declined slowly between 1992 and 2000, falling from 3% to 1% mirroring absolute enrolment numbers. Post-2000 however, participation has increased again and was at 2% or 4,300 students in 2014.

Female students have consistently been under-represented in the engineering subject area and there has been no significant change in the sex ratio over the period of analysis. The sex ratio (Fig. 4.4) was 6 females per 100 males in 2014, compared to a ratio of 7 per 100 in 1992.

Trends in food technology enrolments

The food technology course area has incorporated a large variety of courses over the years including home economics. Food technology courses are the only courses to have consistently demonstrated a female bias in their enrolments over the period of analysis (Fig. 4.4). In 1992 there were 1100 females per 100 male students and by 2014 this had fallen to 370 females per 100 males. A large part of this change can be attributed to the nearly 300% increase in male participation rates between 2000 and 2014 (Fig. 4.2), although the male participation in this course area is still low in comparison to others. Participation rates (Fig. 4.2) fell gradually between 1992 and 2000 but have since recovered steadily. The participation rate of 6.3% in 2014 represents a 150% increase on the minimum participation of 3.9% in 2000. Raw enrolment numbers have mirrored the participation rate trends and courses in food technology accounted for 13,600 enrolments in 2014 (Fig. 4.3),which is an increase of 6,300 on the low point of 7,300 in 2000.

Trends in food and fibre production enrolments

Courses in the food and fibre production course area are classified variously across Australia. In some jurisdictions they include courses such as agricultural science, and in others they are described as agriculture and horticultural studies. This variation in naming conventions, together with the removal of these courses by some states, means this course group is difficult to monitor. However, participation in food and fibre production (Fig. 4.2) appears to have been in steady, yet persistent, decline since 1995. In 1995, enrolments amounted to a participation rate of 2.4%, which has halved to 1.2% in 2014. Raw enrolment numbers show a long, slow decline from around 4,000 in 1992 to just 2,500 in 2014 (Fig. 4.3). Food and fibre production enrolments traditionally had a male bias (Fig. 4), yet from 2009 have been almost at parity. In 1992 the sex ratio was 50 female students per 100 males while in 2014 it was 110 females per 100 males, which is slightly above the cohort norm of 107 per 100. This change is a result of the declining enrolments in this course area being almost entirely comprised of male students (Fig. 4.2). Between 1992 and 2014, male enrolments fell from 2,700 to 1,200 while female enrolments remained static at around 1,300 enrolments.

Patterns in enrolment trends.

Participation rates for three of the subject areas (design technology, food technology and engineering) in the Technologies KLA (Fig. 4.2) demonstrate small increases over the period of analysis and these all follow apparently similar trends. These similarities pose the question, “is there a common underlying factor driving these changes?” A correlation analysis of the participation rates (Fig. 4.5 (left)) shows that there is a moderate to strong correlation between a number of these course areas. The strong positive correlations between food technology and engineering ($r=0.69$, $t(21)=4.32$, $p=.0003$) and food technology and design technology ($r=0.78$, $t(21)=5.80$, $p<.0001$) participation rates pose the question of whether these are trends are being driven by similar factors. Consideration of the residuals after detrending (Fig. 4.5 (right)) suggests that participation in engineering and food technology ($r=0.74$, $t(21)=4.97$, $p<.0001$) are likely to be being driven by similar underlying factors whereas the trends in design technology and food technology ($r=0.52$, $t(21)=2.82$, $p=.010$) are likely the result of unrelated external factors. However, as these results narrowly fail to meet the criteria of being statistically meaningful (Bryhn & Dimberg, 2011) these findings are to be approached cautiously.

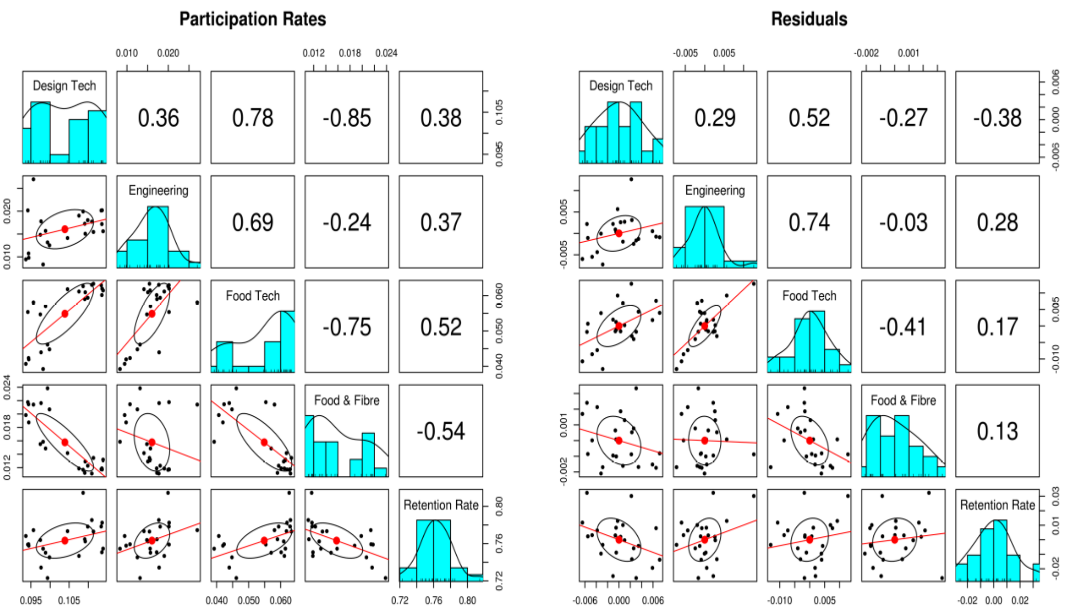

Figure 4.5. Correlation scatterplot matrices showing the relationships between (left) participation rate and (right) residuals following linear detrending for design technologies, engineering, food technologies food and fibre production and overall Year 10 to Year 12 student retention rate for 1992 to 2014.

The course areas are on the diagonals with pair-wise Pearson correlation coefficients above the diagonals and bivariate scatterplots below.

There are moderate positive correlations of the retention rates in these same three course areas with the overall $R_{10\text{-}12}$ retention rate (Fig. 4.5 (left)). However, analysis of the residuals (Fig. 4.5 (right)) suggests that these might be spurious correlations rather than indicative of the growth being due to the increased retention of students into Year 12. It is likely that these trends are also being confounded by the incomplete picture of VET enrolments thus preventing the actual scale and cause of the observed growth from being reliably determined.

Perhaps surprisingly for Australia, which generated 2.4% of its gross domestic product amounting to \$46bn in 2010-11 from agriculture (Australian Bureau of Statistics, 2012), food and fibre production has shown a small yet consistent decline as a school based course area in Year 12. The participation rate for food and fibre production shows statistically significant, strong negative correlations (Fig. 4.5 (left)) with both food technology ($r=-0.75$, $t(21)=-5.17$, $p<.0001$) and design technology ($r=-0.85$, $t(21)=-7.36$, $p<.0001$) as well as a moderate negative correlation with the retention rate ($r=-0.54$, $t(21)=-2.93$, $p=.0081$). Analysis of the residuals (Fig. 4.5 (right)) reveals no statistically significant relationships and so it can be inferred that enrolment changes in this course area are being driven by different influences than the other courses analysed. Most likely is the rise in VET courses as part of Year 12 qualifications. For example, in 2014 in Victoria, 1,202 school students completed VET courses in agriculture and horticulture, compared to 228 students who entered for the examinable agriculture and horticultural studies (unit 4) course; this is a ratio of 5.3:1. In 2001, this same ratio for Victoria was 1.2:1. If these Victorian examples are comparable across the country as a whole—published data are unclear in this regard—then this transition to VET is a significant influence on enrolments in comparable, examinable course areas, that warrants thorough research.

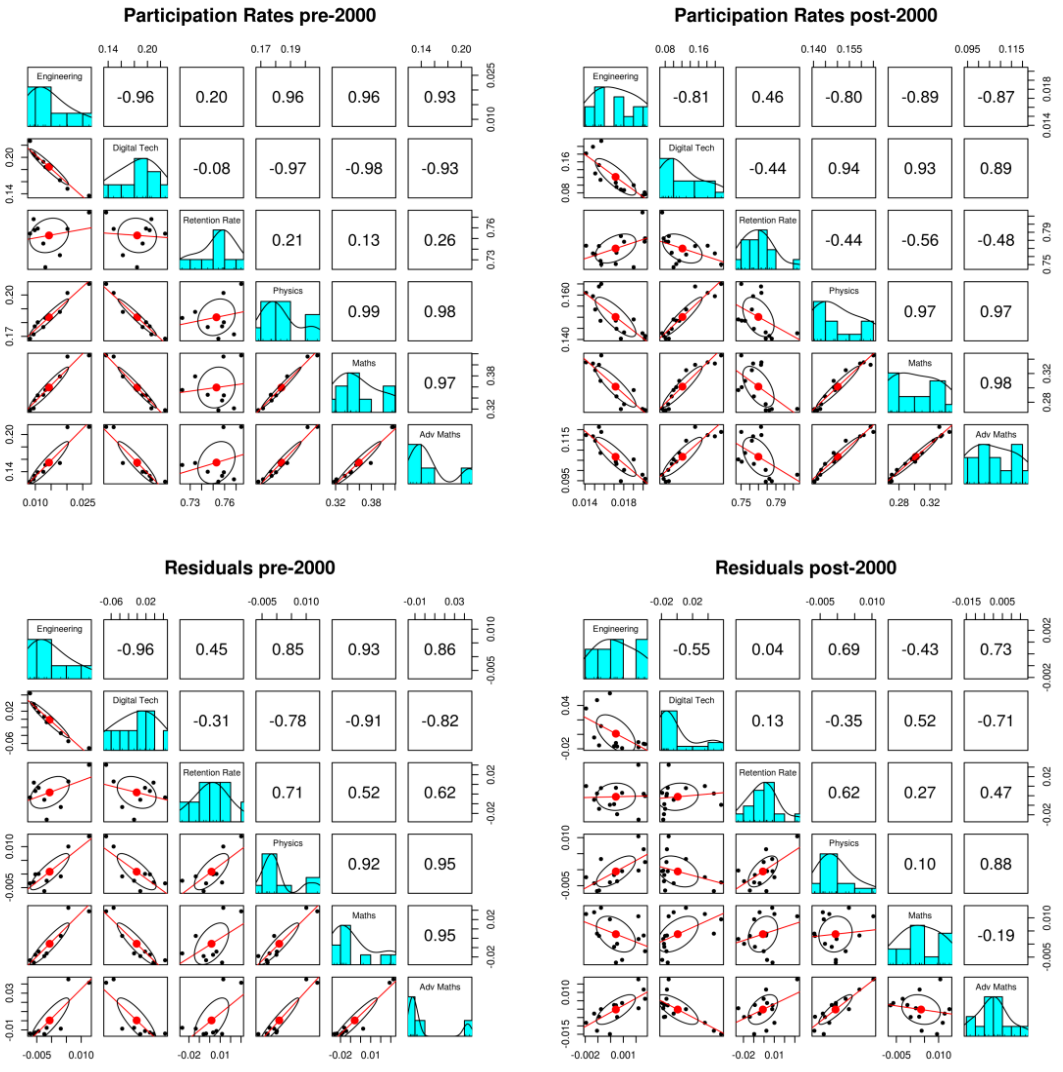

Figure 4.6. Correlation scatterplot matrices showing the relationships between (upper row) participation rate and (lower row) residuals following linear detrending for engineering, digital technologies, overall Year 10 to Year 12 student retention rate, physics, mathematics and advanced mathematics for 1992 to 2000 (left) and 2000 to 2014 (right).

The course areas are on the diagonals with pair-wise Pearson correlation coefficients above the diagonals and bivariate scatterplots below.

Digital technologies exhibits a unique pattern in enrolments (Fig. 4.2) showing strong growth throughout the 1990's yet falling sharply post 2000 to the current point. Figure 4.6 shows that within the Technologies KLA, digital technologies only shows a statistically significant, strong negative correlation with Engineering which is apparent both pre-2000 (Fig. 4.6 (upper left)) ($r=-0.96$, $t(7)=-9.93$, $p<.0001$) and post-2000 (Fig. 4.6 (upper right)) ($r=-0.81$, $t(14)=-4.81$, $p=.0004$). Analysis of the residuals reveals that a statistically meaningful, strong negative correlation existed between digital technologies and engineering before 2000 (Fig. 4.6 (lower left)) ($r=-0.96$, $t(7)=-9.33$, $p<0.0001$) but that this relationship became less strong post-2000 (Fig. 4.6 (lower right)) ($r=-0.55$, $t(12)=-2.26$, $p=.0436$). This strongly suggests the existence of an external factor that promoted digital technologies at the expense of engineering prior to 2000 but that flipped direction and weakened after the turn of the century. While the bursting of the *Dot-Com bubble* in 2000 could reasonably be expected to show an effect on enrolments from 2002 onwards (allowing for the two year lag between enrolment and matriculation), the exact cause of the sudden change in trend cannot be determined reliably. However, this observed turning point coincides with the renewal of course syllabi in many states and territories, the recognition of VET as part of Year 12 qualifications, and also the broadening of the curriculum as a whole to provide wider choice to students. For example, between 2000 and 2001 the total number of available courses across NSW, the ACT, and Victoria (excluding languages other than English), rose by 15% from 187 to 216. The availability of VET courses, a significant number of which were in the Technologies KLA, also increased in this period. However, the difficulty of aligning national VET data with school-based data again prevents definitive conclusions being made regarding scale and cause.

Commonalities with the sciences and mathematics.

The knowledge and skills developed in school science and mathematics courses, in particular physics, mathematics and advanced mathematics, are complementary to the knowledge and skills required by some of the Technologies courses such as engineering and digital Technologies. By combining the Technologies KLA participation data presented here with our prior analyses of the science and mathematics KLAs (Kennedy et al., 2014), which we have extended to 2014, we are able to reveal some interesting correlations between course areas. There are very strong, statistically significant, negative correlations between each of physics ($r=-0.97$, $t(7)=-10.37$, $p<0.0001$), mathematics ($r=-0.98$, $t(7)=-12.45$,$p<0.0001$) and advanced mathematics ($r=-0.93$, $t(7)=-6.62$,$p=.0003$)

with digital Technologies pre-2000 (Fig. 4.6 (upper left)), which become strong positive correlations when only considering the post-2000 data (Fig. 4.6 (upper right)) (physics ($r=0.94$, $t(12)=9.14$, $p<.0001$), mathematics ($r=0.93$, $t(12)=9.08$, $p<.0001$), advanced mathematics ($r=0.89$, $t(12)=6.76$, $p<.0001$)). Consideration of the residuals reveals strong correlations pre-2000, indicative of a common underlying factor, yet much weaker residual correlations post-2000 except for advanced mathematics. This pattern in the trends suggests there was a move away from the traditional science and mathematics course areas towards the modern digital technologies during the 1990s. However, following the turning point when digital technologies began its decline, rather than return to these traditional course areas, students instead transitioned into other course areas in other KLAs from both digital technologies and physics and mathematics. This may be suggestive of a similar set of underlying driving factors affecting the declining participation rates in digital Technologies, physics, mathematics and advanced mathematics.

Engineering shows a strong positive correlation (Fig. 4.6 (upper left)) in participation rate with physics ($r=0.96$, $t(7)=9.74$, $p<.0001$), mathematics ($r=0.96$, $t(7)=8.78$, $p<.0001$) and advanced mathematics ($r=0.93$, $t(7)=6.89$, $p=.0002$) when considered prior to 2000. Again the strong, statistically significant correlations between the residuals (Fig. 4.6 (lower left)) suggests that the trends in these four course areas were being driven by similar external factors during the 1990s. Considering the post-2000 data separately (Fig. 4.6 (upper right)), all three courses reveal strong negative correlations with engineering (physics ($r=-0.80$, $t(12)=-4.65$, $p<.0006$), mathematics ($r=-0.89$, $t(12)=-6.71$, $p<.0001$), advanced mathematics ($r=-0.87$, $t(12)=-6.15$, $p<.0001$)). Physics and advanced mathematics also show strong positive correlations with engineering in their residuals (Fig. =4.6 (lower right)) suggesting that at least some students may have opted to study engineering in place of physics or advanced mathematics at the school level. Examination of raw enrolment numbers between 2000 and 2014 shows that nationally engineering rose by around 2800 students while physics, mathematics and advanced mathematics fell by 300, 450 and 1800 respectively. In the same period the Year 12 cohort expanded by 31,000 students. It is unrealistic to suggest that the rise of engineering in schools, particularly considering its relatively limited offering in schools, is the sole cause of the reported physics and mathematics declines, but it is reasonable to speculate that some of the additionally retained students may have elected to study physics and mathematics in the applied form of engineering rather than in their traditional forms.

Emerging Issues and Implications

The sex ratios presented in Figure 4.4 show a strong bias towards male students for most of the courses analysed. The clear exception to this is food technology, which is strongly biased towards female students. These ratios, which have for design technology and engineering been fairly static, are strongly suggestive of the effects of cultural stereotypes on enrolment decisions.

As already discussed, the movement towards parity of the sex ratio in food and fibre production has been driven by the decline in male enrolments rather than an increase in female enrolments (2700 male enrolments in 1992 to 1200 enrolments in 2014 compared with 1360 to 1330 for female enrolments in the same time). However, enrolment numbers in this course area are too low to be able to draw meaningful conclusions about the underlying factors causing this change in enrolment patterns among male students.

The huge apparent drop in female:male sex ratio in food technology is due to the increase in male enrolments rather than a substantial decrease in female enrolments. In 1992, male enrolments accounted for 1.2% of the cohort, and by 2014 these had more than doubled to 2.8%. Contrastingly, female enrolments had risen by less than a third from 7.3% to 9.5% in the same period. This difference in the rate of change has led to the dramatic change in sex ratio which could possibly be associated with underlying changes in cultural and media stereotypes.

However, perhaps of greatest challenge to our understanding of STEM participation is the change in sex ratio in digital Technologies. Between 1992 and 2014 the sex ratio fell from just under parity to only one in five students being female. This change has been driven by a decline in female participation rates from 12% to 3% of the Year 12 cohort, compared to a decline in participation by males from 15% to 12% in the same period. This result comes despite many programs and initiatives aimed specifically at growing the number of females entering digital careers (Office of the Chief Scientist, 2016), and the societal normalisation of gaming and technology usage among female adolescents (Brand & Todhunter, 2015). Consideration of these national sex based trends alongside other research in this area suggests that the reverse effect identified by McLachlan, Craig and Coldwell-Neilson (2016) between participation rates in digital technologies courses in schools and day-to-day technology could likely have a more significant effect on female students than on males. It would be of great interest to repeat this data collection across a number of international jurisdictions. Comparisons of the national enrolment trends thus revealed would be invaluable in shedding light on the underlying socio-cultural factors driving these changes. However, an analysis of this scale is beyond the scope of this study.

The steep decline in female participation in school digital technology subjects presents a complex and seemingly intractable puzzle (Zagami, Boden, Keane, Moreton, & Schulz, 2015). For example, we currently do not understand the extent to which the decline from near parity to near gender marginalisation over 22 years was associated with curriculum changes across the Technologies KLA, or to broader socio-cultural influences. As Zagami et al. (2015) argue, all the most obvious hypotheses have been explored and initiatives to counter each have been developed, yet we appear no nearer to closing the gap. It is hoped that the detailed enrolment data contributed by our study will assist researchers in exploring this issue further.

Overall, participation in most areas of the Technologies KLA by Australian Year 12 students represents a small, but growing proportion of the total cohort. While this growth is heartening, the low absolute numbers of students studying engineering and the continuing decline of participation rates in digital Technologies should be of particular concern to a nation that aspires to "embrace new ideas in innovation and science, and harness new sources of growth to deliver the next age of economic prosperity in Australia" (Commonwealth of Australia, 2015a). The available Year 12 curriculum has significantly broadened throughout the period covered by this analysis, creating a far greater range of subjects from which students can choose. There has also been a tendency in some states and territories to reduce the minimum number of subjects required for a leaving qualification. Additionally, there has been an apparent increase in students "gaming the system" (Matters & Masters, 2014; Tisdell, 2014) with regard to their course selection in order to maximise their tertiary admissions rank.

In addition to a broadened Year 12 curriculum, a cursory glance at almost any school prospectus suggests that there has been a corresponding broadening of elective courses in Years 9 and 10 (although definitive statistics are unavailable). As courses in the Technologies KLA cease to be compulsory from Year 9 onwards—unlike science and mathematics—it is reasonable to suggest that this increased competition is partially responsible for the lower levels of participation in Year 12; it being relatively less likely that a student will choose to pick up a discipline in Year 11 that they dropped in Year 9 than one similar to a course that has been studied during Year 10.

The strong male bias evident in most of the technologies course areas is echoed in our study of science and mathematics enrolments (Kennedy et al., 2014). Given the policy-aim of producing STEM-proficient graduates, it could be argued that the sex-ratio of STEM courses should be of greater concern to policy makers than enrolment numbers in the STEM disciplines: the participation rate for most technologies, science and mathematics courses has been relatively stable for the five cohorts since 2010. If the STEM disciplines have found their new equilibria levels with regards to the broader curriculum, policy makers might usefully ask what opportunities might exist to promote further female engagement in the domain without negatively affecting male student engagement.

Ultimately, these analyses reveal that participation in technology-based courses is growing in most areas, albeit slowly. However, given the focus on school STEM of the last few years and the assertion that STEM can be a cornerstone of creating technologically aware and literate citizens then it is important to understand why more students are not electing to study Technologies at school. Phrased like this, it makes the collapse of enrolments in digital Technologies of particular concern especially given the pervasiveness of computers and the future needs for computational thinkers. However, examining enrolment data can only reveal the general trends and further investigation is required to understand why, when and how they make the decision to turn away from technology courses and to also understand what they elect to study to replace them.

4.3 Statement of authors' contribution

We, the PhD candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in this thesis and they have accepted the candidate's contribution as indicated in the Statement of Originality.

	Author's Name	% of contribution
Candidate	JohnPaul Kennedy	80
Other Authors	Dr Frances Quinn	10
	Associate Professor Terry Lyons	10

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25th September 2018

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Dr Frances Quinn
(Principal Supervisor)
25th September 2018

4.4 Statement of originality

We, the PhD candidate and the candidate's Principal Supervisor, certify that the following text, figures and diagrams are the candidate's original work.

Type of Work	Page Number/s
Figure 4.1	79
Figure 4.2	80
Figure 4.3	80
Figure 4.4	81
Figure 4.5	85
Figure 4.6	86

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25th September 2018

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25th September 2018

Chapter 5: The School Science Attitude Survey: A new instrument for measuring attitudes towards school science.

5.1 Introduction

Chapter 1 established two main research themes (p. 5) for this study. The poster and paper presented in Appendix B, highlights some of the links between positive attitudes and students' enrolment intentions; yet that study (Kennedy, 2015) was necessarily limited in scope and depth. Research question RQ6, however, requires that attitudes be able to be measured broadly and reliably on the large-scale. In Chapter 2 I briefly explored some of the many frameworks that have been utilised in an attempt to understand the formation of desirable attitudes towards the STEM disciplines. Yet the instruments that have been developed around these frameworks have tended to be either narrowly focussed on an aspect of a STEM discipline or else broadly focussed on school as a whole. Very few instruments or studies have been able collect data that can be considered to be simultaneously broad and deep.

The article presented in this chapter first examines the concept of attitudes in an attempt to form a useful consensus definition for this often used term. I then summarise ten existing science attitudes instruments in an attempt to distil the commonalities in their measured constructs. Combining this summary table with the literature surveys of Osborne, Simon and Collins (2003) and Potvin and Hasni (2014), I identify five theoretical attitudinal constructs that appear to offer a level of insight into explaining students' attitude formation and hence by extension their enrolment intentions.

The article then discusses the problem of survey apathy that previous research teams have faced when attempting to measure such a broad range of constructs. This potential problem was particularly concerning as my research design intended that I gather attitude ratings towards multiple disciplines, at multiple times, for a large sample of students. In order to address this issue I developed a new instrument that could make use of digital technologies to simplify the data collection process and that made use of single item measures in order to streamline the experience for students. Given the inevitable controversy that surrounds the use of single item measures (e.g., Gardner, Cummings, Dunham, & Pierce, 1998; Oshagbemi, 1999; Wanous & Reichers, 1996) the article then details the development and validation of this new instrument in significant detail.

As a result of this thorough analysis and validation, six attitudinal constructs were developed which are utilised throughout the subsequent chapters of this thesis in forming explanations for observed changes in attitudes. Some possible visualisations and applications for the resulting data are discussed including the development of a Subject Attitudinal Profile which is used significantly in Chapters 6 and 7 of this thesis. I conclude that, under appropriate circumstances, it is possible to make use of an attitude instrument to collect data that is both broad and deep while remaining reliable and valid at the construct level. This verification process is central to the investigation of all research questions associated with research theme RT2 "How do student attitudes towards STEM-related courses change over time in comparison with other school subjects?". This innovative instrument opens the doorway to a new way of understanding attitudes in the context of school subjects.

5.2 Journal Article 3

This article was originally published in the International Journal of Research and Method in Education available at https://doi.org/10.1080/1743727X.2016.1160046. The original appendices to this article are include in this thesis as Appendix C1 and Appendix C2.

Cite this article as:

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5.3 Article Impact

At the time of submission of this thesis, this article had been cited eight times based on Google Scholar metrics and has had both national and international impact.

Of particular note are two studies that take the instrument detailed in this article and further develop and refine it for specific circumstances. Firstly Blackweir (2016) made use of the instrument described in this article which she then validated and extended it for use in the mathematics domain. Secondly by Toma and Meneses Villagrá (2018) who translated the instrument into Spanish, revalidated it and found that its structure and psychometric underpinnings held when used with Spanish upper primary school pupils.

The School Science Attitude Survey: A new instrument for measuring attitudes towards school science.

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There have been many attempts over the last five decades to measure students' attitudes towards school science. The majority of these studies have investigated attitudes towards limited aspects of science or school science and utilised relatively large numbers of items to draw snapshot summaries of the educational landscape at particular times. An understanding of attitudes towards science, and how these change over time, is of particular importance to educators in Australia and farther afield, who are forming a response to the continued declines in enrolments seen in post-compulsory science courses. We identify a gap among the available instruments for a tool that can measure multiple facets of attitudes using a minimal number of items, while being suited for use in pre/post test and longitudinal studies by educators and educational researchers alike. In this article we describe the definition, validation and statistical refinement of a digital survey tool that uses single-item web-based visual analogue scales to measure five key perceptions of school science that lead to the formation of a Science Attitude Profile. We also offer a suggested item to measure students' enrolment intentions towards post-compulsory science courses. Finally recommendations are made as to how these resulting profiles might be analysed by educators at the student level, and by educational researchers at the group level over time. We suggest that a particular strength of the tool is the ability to provide a 'does it work?' critique of various interventions implemented by educators and inform educational policy.

Introduction

There have been significant changes to the patterns of post-compulsory enrolments in secondary education in Australia over the last few decades. Researchers have identified continuing declines in many subject areas (e.g., Ainley, Kos, & Nicholas, 2008; Fullarton, Walker, Ainley, & Hillman, 2003; Kennedy, Lyons, & Quinn, 2014; Lyons & Quinn, 2010; Mack & Walsh, 2013) but most notably in the enabling sciences and advanced mathematics. The declines in Science, Technology, Engineering and Mathematics (STEM) related subjects are of particular concern to policy makers (e.g., Lowe, 2014; Office of the Chief Scientist, 2013) as these are seen as problematic for the future direction and strength of the national economy.

Declining enrolments and weak attitudes towards STEM subjects have been also noted in many countries across the world including England and Wales (Smith, 2011), France (Charbonnier & Vayssettes, 2009), Israel (Trumper, 2006), the US (Sadler, Sonnert, Hazari, & Tai, 2012) and China (Cheng & Wan, 2016). The widespread nature of these concerns, both geographically and culturally, indicates that a better understanding of what constitutes and forms positive attitudes towards school needs to be of global priority.

The rationale for this paper is twofold. First, given the complex nature of attitudes, we argue that a deep understanding of a particular student's attitudes towards any individual school subject area requires an understanding of their attitudes to the different components of their own particular and personal subject mix. The second reason for this paper is that, to our knowledge, no reliable questionnaire has yet been developed that can measure the many facets of students' attitudes towards school science within—and relative to—the wider context of attitude to school. A number of the studies outlined in our literature review in Table 5.1 (e.g., Barmby, Kind, & Jones, 2008; Morrell & Lederman, 1998; Simpson & Oliver, 1985; Turner & Ireson, 2010) showed changes towards science attitudes over time. However, most of the studies cited use simultaneous measurement of similar cohorts to make these comparisons. There is therefore a need for a quantitative instrument that facilitates longitudinal study of attitudes of the same cohort, to contribute to our understanding of when and possibly how relative attitudinal changes occur.

Hence the overarching aim of this small-scale initial study is to explore the potential in developing a reliable web-based instrument—a School Science Attitude Survey (SSAS)—to facilitate subsequent longitudinal studies into students' attitudes to school science, in relation to their other subjects. The intention is for the SSAS to be valid for regional, rural, remote and metropolitan school students as well as for male and female students. This article ultimately addresses two questions:

1) Can a single, web-based instrument be developed to measure multiple facets of a student's attitude towards school science?

2) Can student attitudes towards school science be reliably measured in a time-efficient manner using single-item measures?

Understanding Attitudes

Understanding and measuring attitudes towards school science has long been an aim of researchers in education (Archer et al., 2010; Danaia, Fitzgerald, & McKinnon, 2013; Ebenezer & Zoller, 1993; Jenkins & Nelson, 2005; Lyons & Quinn, 2010; Osborne, Simon, & Collins, 2003; Potvin & Hasni, 2014; Simpson & Oliver, 1985, 1990). The majority of these studies involve quantitative analysis of Likert-type (LT) data (e.g., Simpson & Oliver, 1990) while involve more qualitative components often in the form of interviews (e.g., Archer et al., 2010; Danaia et al., 2013; Lyons & Quinn, 2010)

The notion of attitude in the literature is often confusingly defined, and has been interpreted in various ways by different researchers. Simon and Osborne (2010) discuss the constructs of attitudes towards science *in general* and attitudes towards *doing* school science and conclude that attitudes are multifaceted constructs where the sub-constructs contribute in varying degrees to a student's overall perception of school science. They assert that 'it is the perception of school science, and the feelings towards undertaking a further course of study, which appear to be most significant in determining children's decisions about whether to proceed with further study of science post-compulsory education' (Simon & Osborne, 2010, p. 240). The Science Framework developed by the OECD for the 2015 PISA assessment (OECD, 2013) notes that 'Peoples' attitudes towards science play a significant role in their interest, attention, and response to science and technology' and that, 'such attitudes also support the subsequent acquisition and application of scientific and technological knowledge […] and lead to the development of self-efficacy' (OECD, 2013, para. 74)

Much research into student attitudes tends to fall into two camps; specific research into attitudes towards school science (e.g., Barmby et al., 2008; Fraser, 1982; George & Kaplan, 1998; Jenkins & Nelson, 2005; Lyons, 2006; Lyons & Quinn, 2010; Osborne et al., 2003; Schreiner & Sjøberg, 2004) and research into general attitudes towards school (e.g., Abu-Hilal, 2000; Ainley & Bourke, 1992; Luiselli, Putnam, Handler, & Feinberg, 2005). Some researchers (e.g., Aikenhead & Ryan, 1992) focus on the sociological aspects of science beyond the confines of school, while others are more tightly focused on attitudes towards school-science (e.g., Chen, 2006). Some authors (e.g., Simpson & Oliver, 1985) have attempted to capture a number of distinct aspects and distil them into a single construct while others (e.g., Moore & Foy, 1997) describe the many facets of attitudes as an attitude profile. The varied interpretations of 'attitudes' are highlighted in Table 5.1, which summarises some of the different research foci and constructs that have been investigated in attitudinal research and the instruments used over the last four decades.

Table 5.1: An overview of a sample of existing instruments, and studies that have made use of them, summarising the Attitudinal Constructs investigated, the response formats used, and the key findings of the studies.

Instrument and studies that utilise it.	Attitudinal constructs investigated	Number of items and response format
Test of Science Related Attitudes (TOSRA) (Farenga & Joyce, 1998; Fraser, 1982; Turner & Ireson, 2010)	• Social implications of science, • Views on scientists • Scientific inquiry, • Adoption of scientific attitudes, • Enjoyment of science lessons. • Leisure interest in science, • Scientific career interest	Paper survey with 70 discreet Likert-type items
Simpson-Troost Attitude Questionnaire (Owen et al., 2008; Simpson & Troost, 1982)	• Science self-concept • Science anxiety • Achievement motivation • Views on science classes • attitudes of friends and family in support of science	Paper survey 60 with discreet Likert-type items measuring 15 sub-dimensions.
Attitude toward Science Scale (Simpson & Oliver, 1985, 1990)	• General attitude towards Science • Motivation to achieve. • Gender differences	Paper survey with 60 discreet five-point Likert-type items
Science Assessment Instrument (Bateson, John, & Branch, 1986; Ebenezer & Zoller, 1993)	• Classroom practices and activities • General perceptions of school science	Paper based survey with 16 Likert-type items plus 29 background information questions. Survey was followed by selected interviews
The Measure of Students' Attitudes Toward School & Science Attitude Scale for Middle School Students (Misiti, Shrigley, & Hanson, 1991; Morrell & Lederman, 1998)	• General Attitude to School • General Attitude to Science	Two paper based survey instruments used with 10 and 23 discreet Likert-type items respectively.
Views on Science-Technology-Society (VOSTS) (Aikenhead & Ryan, 1992; Ryan & Aikenhead, 1992)	• What is Science? • The value of science. • How is scientific consensus reached? • Characteristics of scientific knowledge.	Paper survey with 114 multiple choice statements based on previous qualitative response patterns.

Instrument and studies that utilise it.	Attitudinal constructs investigated	Number of items and response format
A Structural Model of Attitudes Towards School Subjects, Academic Aspiration and Achievement Custom SEM Model and questionnaire (Abu-Hilal, 2000)	• General School Attitude, • Attitude towards the study of English, • Attitude towards the study of Mathematics • Attitude towards the study of science • Attitude towards the study of social sciences • Relevance of school subjects to the present. • Relevance of school subjects for the future	Paper based survey consisting of 6 discreet Liket-type general items plus an additional 2 Likert-type items per academic domain.
Changes in attitude about the relevance of Science (CARS) (Siegel & Ranney, 2003)	• Relevance of school science to students	Three paper based surveys each of 25 discreet five-point Likert-type items drawn from a pool of 59 items.
Relevance of Science Education (ROSE) (Schreiner & Sjøberg, 2004; Sjøberg & Schreiner, 2010)	• What I want to learn about, • Science and my career, • Me and environmental challenge, • Science classes, • Out of class experiences, • Opinions about science and technology, • Views about myself as a scientist.	Paper survey with 245 four-point discreet responses of the form Never, , , Often
Attitude to Science Measures(Barmby et al., 2008; Kind, Jones, & Barmby, 2007)	• Attitudes to school science • Attitude towards practical work in science • Attitude towards science outside of school. • Importance of science, • Self-concept in science • Future participation in science • General attitude towards school	Paper survey using 46 discreet Likert items. Survey followed up by group interviews with 44 participants.

The summary of the literature presented in Table 5.1, together with the key literature surveys of Osborne et al. (2003) and Potvin and Hasni (2014) reveals five common themes that seem particularly relevant to students forming positive attitudes towards school science.

- Perceived enjoyableness of school science
- Perceived difficulty of school science
- Perceived self-efficacy of the student in school science
- Perceived relevance of school science for the student's everyday life
- Perceived usefulness of school science for the student's future career.

Existing Instruments

Blalock et al. (2008) conducted a review of 66 existing science attitude instruments and showed that many of these were lacking appropriate psychometric data to warrant generalised use. The majority of the studies that we considered (Table 5.1), met the criteria of Blalock et al. that the instrument authors have published reliability and validity evidence for their use of their instrument and that the instrument has been used in replication studies.

Almost all of the instruments outlined in Table 5.1 make use of multi-item Likert scales of one sort or another, measure just one or two attitudes, and are generally designed to give a detailed snapshot of attitudes at a given point in time using relatively large numbers of items (>50). Some researchers (e.g., Siegel & Ranney, 2003) have recognised the need to be able to measure the attitudes of the same participants at different times. This requires the compromise of a reduced number of items, to reduce survey apathy and sample attrition, while not losing measurement power.

The majority of the questionnaire studies in Table 5.1 used paper copies of their instruments or simple digitised versions of these paper formats. However, the rise of the World Wide Web has greatly facilitated the access of potential participants to online surveys. A number of researchers (e.g., Rada & Domínguez-Álvarez, 2014) have administered comparison studies between web-based surveys and their paper counterparts. In general these researchers have found that the results from these two response methods are comparable and that in fact the web-based instruments may have a number of advantages. Web based instruments often have fewer missing responses (Boyer, Olson, Calantone, & Jackson, 2002), are more effective and cost-efficient (Fricker & Schonlau, 2002), can give access to unique and broad populations (Wright, 2005), and allow for unique approaches to flexible techniques such as contingent coding (Boyer et al., 2002). There are however a number of drawbacks to this approach. Most commonly stated is the fear of the introduction of a sample bias that arises due to the inequity in Internet access amongst a target population (e.g., Ross, Månsson, Daneback, Cooper, & Tikkanen, 2005; Couper, 2000). It has also been suggested (Manfreda, Batagelj, & Vehovar, 2002) that designers of web-based instruments may need to pay greater attention to elements such as graphical presentation, font and item wording than traditional paper-based instruments.

A New Instrument Using Single-Item Measures

A new solution to the measurement of attitudes may come from the use of single-item measures as this would reduce the number of required items significantly and alleviate some of the problems of long surveys outlined previously. Yet the use of single-items is itself not without controversy. Oshagbemi (1999) suggested that single-item measures can produce data that is positively skewed and hence biased. However, a study in epidemiology (Littman, White, Satia, Bowen, & Kristal, 2006), where the practical limitations on the number of items to be used are similar to this study, concluded that single-item measures can be just as reliable as multi-item scales. Gardner et al. (1998) showed that there is often little practical difference between single-items and mutli-item scales especially when combined with non-Likert scales. Wanous and Reichers (1996) observed that the use of a single-item measure is often considered a 'fatal error' by many researchers. Even so, they go on to describe how single-item measures can be useful in measuring both concrete facts and psychological constructs when they are well defined and readily understood by participants and researchers alike. Wanous and Hudy (2001) concluded that for a single-item to be considered reliable it should ideally have a reliability estimate greater than 0.70 for individual level data and 0.80 if derived from group level data.

Wanous and Hudy (2001) also showed that single-item reliability estimates can be made using Spearman's (1904) correction for attenuation formula by assuming that the true correlation between a single item and a multiple-item measure of the same psychological construct is 1.00. A reliability estimate for the single-item can be therefore calculated given the reliability of the multiple-item measure and the observed correlation between the single and multiple-item measures.

Selecting Initial Questions

Although it is clear that attitudes to one subject are formed within the broader context of general attitudes to school, it was decided to focus the initial development of the instrument only in the domain of school science. This approach to the problem allows for a rigorous development process to be followed and the validity and usefulness of this new approach to be assessed. We have designed the instrument—the School Science Attitudes Survey (SSAS)—to measure a student's Attitudinal Profile (AP) to the area of school science. The instrument incorporates the five common themes that recur throughout the attitudinal literature outlined above. Despite their limitations, these themes offer a sound starting point for the development of a multifaceted attitudinal instrument and are included as the following school science Attitudinal Constructs (AC); Enjoyableness (E), Difficulty (D), Self-Efficacy (S), Relevance (R) for the student's everyday life, and Usefulness (U) for the student's future career.

In addition to these ACs that have emerged from previous literature, Khoo and Ainley (2005) reported a particularly high correlation between the intentions of Year 9 students to proceed to Year 12 and their actual participation. As enrolment intentions appeared to offer the potential of a proxy for attitudes, a sixth AC was therefore defined and investigated in this study; Enrolment Intentions (I) for a course in the Science KLA.

In order to ascertain suitable single-items for use in the SSAS 46, potential items were selected from four existing well trialled and validated surveys; The Relevance of Science Education (ROSE) (Sjøberg & Schreiner, 2010), the Test of Science Related Attitudes (TOSRA) (Fraser, 1982), Perceived Challenge and academic Self-Concept scale (PCSC) (Wilson, 2009) and Views About Sciences Survey (VASS) (Halloun, 2001). In addition to these items, 22 new items were also developed for the initial pool bringing the total number of items to 68. These selected items were used to form multi-item measures for each of the ACs described above. The wording of each of the items used in the initial question pool, their intended AC, and their original source are shown in Appendix B. All items were checked for initial construct validity in consultation with a group of subject matter experts.

Response Formats

The instrument at the focus of this study was developed for use online using PHP and JavaScript, meaning that items could effectively use any of three response formats:

- traditional five point Likert type (LT) scales scored from -2 to +2;
- visual analogue scales (VAS) scored from -50 to 50 with semantic differential (SD) endpoints;
- VAS scored from -50 to 50 with Likert-like strongly-agree and strongly-disagree endpoints.

Friborg, Martinussen and Rosenvinge (2006) showed that SDs produced data that was more unidimensional and interpretable than LT items. The SD system can effectively use either extreme adjectives or more neutral adjectives as the dipole. Osgood, Suci and Tannenbaum (1957) suggested that the extreme dipole style of item can lead to a more commonly understood and predictable scale, however the use of more neutral choices can yield better understanding of the meaning ascribed by participants to the words used and hence the construct. It has also been shown by Funke and Reips (2012) that in Internet based instruments, the combination of SDs and VAS yield better data quality than traditional LT scales.

Instrument Structure

In order to investigate the most suitable of these response formats for each AC, the items for each scale were divided approximately equally between the three response formats. For the purposes of analysis, all items were subsequently scaled to a common scale of -50 to +50 with a neutral point of 0. The response formats of the items were variously programmed as a horizontal slider (fig 5.1 (upper)) or as horizontal groups of radio buttons (fig 5.1 (lower)) and initialised to the neutral value of zero. The VAS slider allowed participants to select any integer value between the two endpoints—50 to -50—thus resulting in a good approximation of a true analogue scale. One of the advantages of the use of a VAS slider over a Likert item in measuring attitudes is that it results in continuous—rather than discrete—data and is therefore more likely to fulfil the assumptions of more powerful parametric analytical techniques. In either style of response format, only the extreme points of the items were labelled. The items were grouped across seven pages by firstly response format and then secondly by AC. The design of the final instrument was intended to take participants between fifteen and thirty minutes to fully complete.

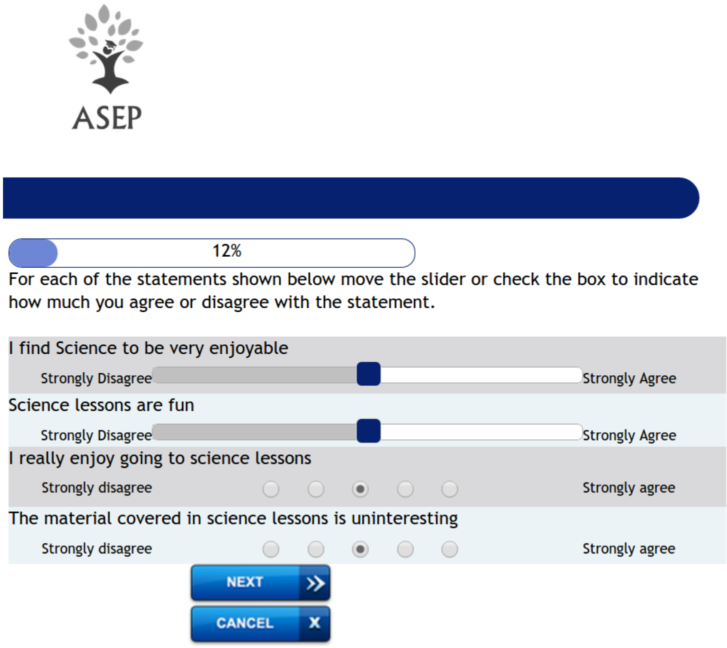

Figure 5.1: Screen-shot showing the implementation of visual analogue scale Likert-type item (upper) and five-point discreet Likert-type item (lower) response formats as used in the web-based data collection interface.

Refining the School Science Attitudes Survey

The warnings of Blalock et al. (2008), the wide range of instruments from which items have been drawn, and the range of response formats available, caused the adoption of a wide range of analyses and treatments—including some from outside the normal scope of educational research—in the quest to ensure methodological validity for the SSAS.

Face Validity of Pool Items

As the initial pool of items selected for this study was based on items from four existing instruments as well as new items especially developed for this study, two post-hoc small group interviews were held to validate the items' suitability to measure the underlying ACs. Focus Group A consisted of nine (six male, three female) Year 7 (12-13 year old) students. Focus Group B consisted of five (three male, two female) Year 10 (15-16 year old) students. The two groups were given the 68 item statements on single pieces of paper and asked to sort them into ‘as many or few categories as necessary that have a common idea running through them’. Group A produced 5 categories (a-e) and Group B produced 8 categories (i-viii), and these are identified in Table 5.2. The students' explanations and description of each category are shown in Table 5.2 alongside the intended AC. As can be seen in these tables the ACs Self-Efficacy (S) and Difficulty (D) clearly and unambiguously correspond to just single-item categories formed by each interview group as the items appear in just one category. By collating categories that correspond to the students' positive and negative attitudes, the ACs Enjoyableness (E) and Usefulness (U) are also almost unambiguously identified by the two focus groups. Both groups of students associated the Relevance (R) items into three major categories suggesting that Relevance (R) is likely to not be a unidimensional AC.

Overall, these focus group analyses revealed that the constructs that we intended the items to represent were generally well understood by participants in both the younger (Group A, Year 7) and the older (Group B, Year 10) groups. We conclude, although cautiously with regards to the Relevance (R) AC, that the selected items are suitable from the perspective of construct validity to further develop into final scales for the SSAS and from which to identify potential single-items.

Table 5.2: Descriptions of Item categories offered by members of two post-hoc focus groups.

Similar descriptions offered by the two focus groups that describe similar groups of items have been arranged horizontally adjacent. The corresponding intended Attitudinal Constructs are also indicated.

Group A - Year 7			**Group B - Year 10**		
Category Code	**Description**	**Attitudinal Construct**	**Category Code**	**Description**	**Attitudinal Construct**
d	Positive feelings towards a students past performance in school science	E	iv	Positive feelings about being good at Science	S
e	Negative feelings towards a students past performance in school science	D	v	Negative feelings about understanding science content and knowledge.	D
c	Positive and negative general feelings about science lessons	E,R,I	ii	Positive feelings about enjoying science lessons	E
			vi	Negative general feelings about school science	E
a	Things I want to learn about and ways I can improve.	S,R	iii	Positive feelings about what a student wants to learn about in school science	R
b	Positive and negative views on the applications of science for the future	U,R,I	viii	Positive feelings about the usefulness of science for the future.	U,R,I
			vi	Negative feelings about the prospect of science for the future.	U,R,I
			i	Positive attitudes towards public spending on Science	R

Determining the Dimensionality of the Attitudinal Constructs

To address research question 1 it was necessary to confirm the extent of the unidimensionality of the items used for each of the five Attitudinal Constructs and thence to determine the most appropriate single-item from each scale that could be used to measure the factor in a whole-school-wide instrument.

A small, sample of students from 18 New South Wales schools was recruited in two phases to participate in the initial development of the instrument. The schools represented both co-educational and single sex schools; government, Catholic systemic and independent schools; located in metropolitan, regional and rural areas. All students were in Year 7 (12 or 13 years old) at the time of data collection. After two rounds of collecting data, 124 participants had answered the survey with 116 complete responses.

Analyses were carried out using the statistical software ‘R’ (R Core Team, 2014) and the psych (Revelle, 2014a), stats (Team, 2014), and GPArotation (Bernaards & Jennrich, 2005) libraries. A graphical approach to the initial analysis was adopted, in addition to the conventional tabular output, as it was felt to be particularly useful in identifying trends, patterns and dimensionality within the analysis results.

For each AC a correlation analysis of its constituent items was carried out and figure 5.2a shows a scatterplot of matrices with bivariate scatterplots below the diagonal; the Pearson product-moment correlation coefficient (PCC) above the diagonal; and frequency distribution histograms with overlaid kernel density plots on the diagonal. A heat map (Fig. 5.2b) was also used to highlight patterns between the bivariate correlations between items. Any uncorrelated items ($|PCC|<0.5$ for all correlations in a row) were suppressed in the dataset for the future stages of analysis. All items were also checked to ensure that they adequately met the assumptions of normality required for the use of parametric statistics by calculating Shapiro-Wilk’s W-statistic. Items with $p>.1$ were rejected from further analysis in accordance with the recommendations of Royston (1995).

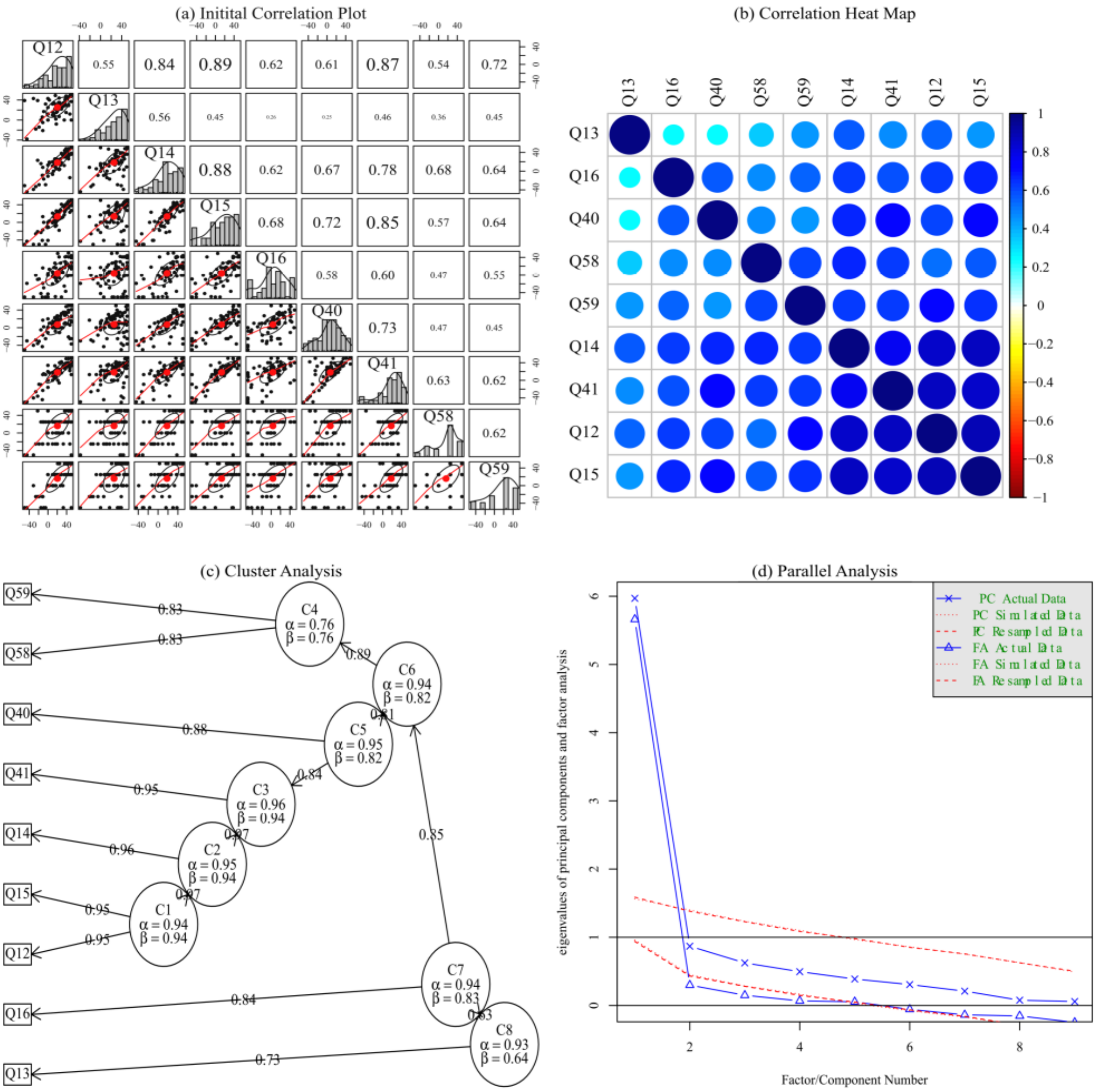

Figure 5.2: (a-d) Graphical representation of the process to identify the dimensionality of a group of items hypothesised to measure the same Attitudinal Construct.

(a) an initial pair-wise correlation plot showing correlation plots below the diagonal, single-item kernel density plots and distribution histograms on the diagonal and Pearson correlation coefficient above the diagonal. (b) a pair wise correlation heat map of the items. The darker shades of blue highlight relationships with stronger positive correlations. Clusters of items appear as groups of similar density. (c) the output of an item cluster analysis. A unidimensional group of items is more likely to show even branching in this output than a multi-dimensional group of items. (d) output of the Very Simple Structure process showing a peak in the fit at the appropriate number of factors present in the group of items.

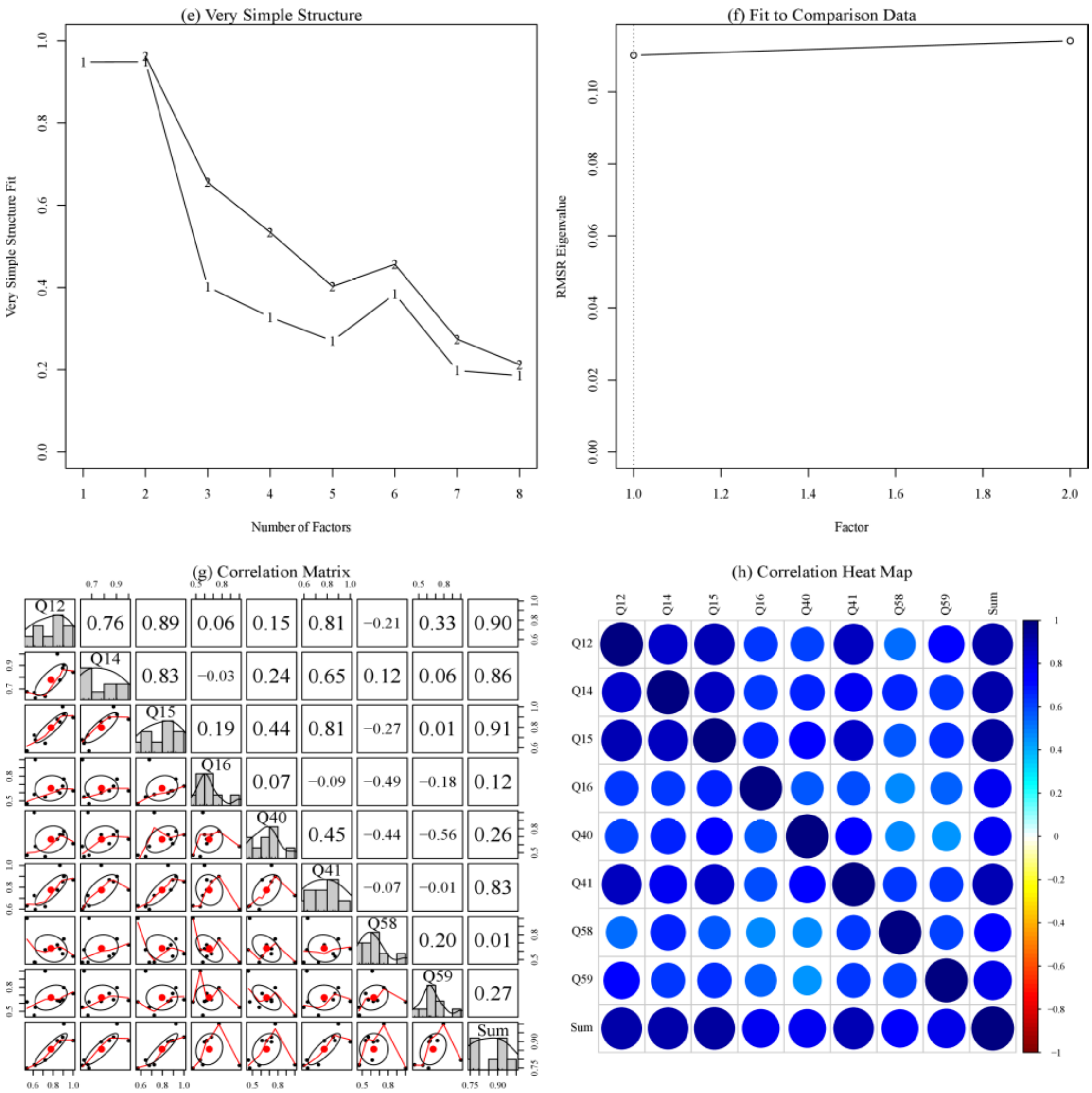

Figure 2: (e-h).

(e) scree plots comparing the factor structure of the actual data to simulated normal data sets of identical size. (f) output of a parallel analysis using simulated data of comparative size and structure. (g) a pair-wise correlation plot showing the relationship between the group items and the sum of the retained group items used for suggesting a suitable single-item. (h) a heat map of the retained group items to identify any remaining granularity in the underlying structure.

The items that remained after this process were analysed for internal consistency—obtaining the coefficients alpha (Cronbach, 1951) and beta (Revelle, 1979)—using functions available in the psych package (Revelle, 2014a). As it is probable that the individual item scores may violate the equal item loading assumption of coefficient *alpha*, *lambda-6* (Guttman, 1945) was also determined. Where $\alpha>\lambda_6$ equal item loading can be considered likely and *alpha* gives a reasonable estimate of reliability; in situations where $\alpha<\lambda_6$ the loading can be considered 'lumpy'—in reference to the level of microstructure in the data subjected to a unifactorial test (Revelle, 2014b)and internal consistency may be better determined by coefficient *beta* (Revelle, 1979) which gives the worst case split-half reliability of the group of items. Cooksey and Soutar (2006) suggested that if *beta* was found to be 15 to 20 points lower than *alpha* for a particular group of items, then this should be interpreted as a possible indicator of multidimensionality. Items were dropped stepwise from the groups, so as to improve the overall reliability, if their absence increased *alpha* by at least 0.02 or if the item cluster graph (Fig. 5.2c) suggested that an item belonged to a cluster of size 1.

The reduced datasets were then checked for dimensionality using four independent methods. The overall aim of this part of the process was to confirm the expected unidimensionality of each group of items corresponding to each AC, or to explain any unintended underlying structure. Firstly, hierarchical item cluster analyses were examined. If the higher order analyses did not add new clusters, other than forcing single-items out of the main cluster, it was inferred that the underlying structure at a complexity of 1 is a good approximation of unidimensionality.

The complexity of a structure indicates the number of factors that a particular item loads on; that is, in a complexity 1 solution each item is constrained so as to load on only one factor and all item loadings except the greatest are ignored. In testing for unidimensionality it is therefore reasonable to only consider complexity 1 solutions.

Second, the data were subjected to the Very Simple Structure (VSS) technique (Revelle & Rocklin, 1979) with an oblique (oblimin) rotation. The graph produced (Fig. 5.2e) by the VSS procedure peaks at the optimum number of latent factors present in a dataset for a solution of given complexity. We considered only solutions of complexity 1 with unidimensionality being again inferred by a peak in the complexity 1 curve with one factor.

Lastly, the data were subjected to two separate parallel analyses; first by using a random data set of the same size (Fig. 5.2d) (Horn, 1965), and then using simulated ‘comparison data’ (Fig. 5.2f) according to the technique suggested by Ruscio and Roche (2012).

In cases where this four-fold analysis of dimensionality inferred a unidimensional structure to the underlying subset of items, the sum of the item scores was calculated and a new correlation matrix (Fig 5.2g) and correlation heat map (Fig 5.2h) were generated. The item with the highest correlation to the summed scale score was selected to represent the AC and an estimated reliability was calculated.

In the two cases—Usefulness (U) and Relevance (R)—where the tests in this four-fold analysis procedure were in disagreement about the level of structure in the subset of items and inferred more than one latent factor, the data were subjected to a series of principal components analyses (PCA).

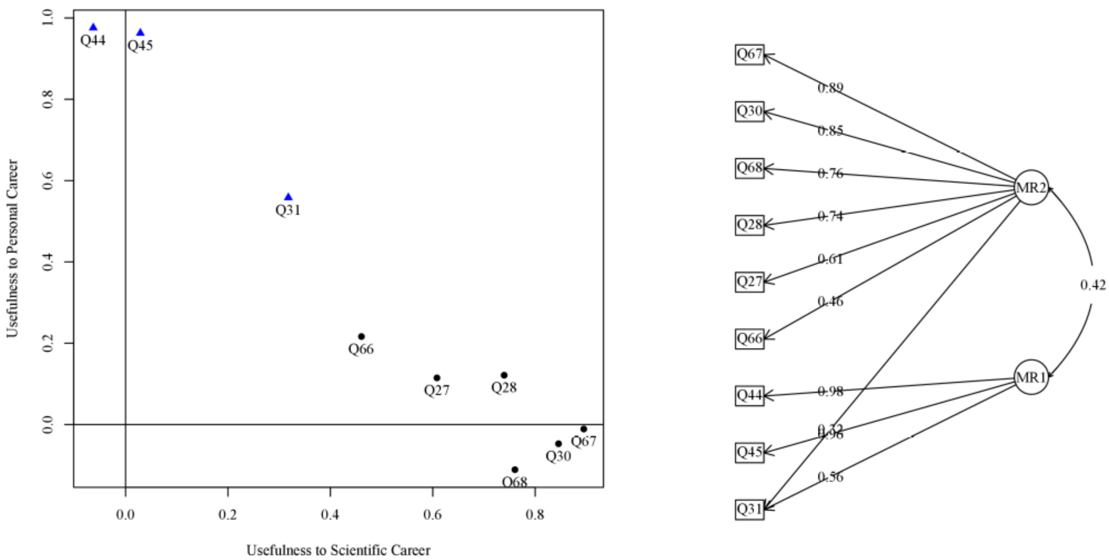

Figure 5.3: Graphical representation of selected parts of the process to describe the dimensions of item groups identified to have a multi-dimensional structure.

(left) Factor loading plot showing the loading of each item on each identified factor. (right) model of the underlying factor structure of the item groupings showing the relative loadings of each item on each latent factor.

The number of factors to extract using this PCA was determined through comparison of the VSS criterion and Velicer's (1976) Minimum Average Partial criterion. The deciding requirement of these two solutions was the interpretability of the extracted dimensions. Each dimension of the PCA (Fig. 5.3 (left)) was examined and described based on the concepts contained in the items lying closest to the dimensional axes. The constituent items of the AC were then regrouped into sub-groups based on the factor loadings (Fig. 5.3 (right) and Tables 5.4 and 5.5) in an attempt to define unidimensional sub-factors that were then analysed using the procedure previously outlined.

As before, reliability estimates, using alpha and beta, were calculated for each sub-group and the single-item that correlated to the summed sub-factor score was selected to represent the sub-factor. The items representing the sub-factors and their various combinations of linear sums were then correlated against the full scale AC in an attempt to measure the full factor using as few items as possible. The estimated overall reliability in these n-dimensional constructs was determined using coefficient *omega* (McDonald, 1999) determined using the hierarchical structure solution.

Table 5.3: Summary of analyses identifying the measures of full scale reliability for each of the Attitudinal Constructs, the dimensionality of each grouping of items and the correlations and reliability estimates of the selected single-items selected to represent each Attitudinal Construct.

In the case of the multi-dimensional Factors Relevance and Usefulness the correlations and reliability estimates in parenthesis for each of the sub-scales (light blue shading) correspond to the relevant statistics should that single-item be selected to represent the scale as a whole. Double parenthesis represent the same statistical concept for the sub-scales of Personal Relevance (dark blue shading).

Attitudinal Construct	Number of Items retained in Scale	Items rejected	Reliability of full scale				Dimensionality	Single-item Number	Single-item Correlation	Expected Reliability
			α	λ_6	β	ω_t				
E	12	Q38,Q36	0.98	0.98	0.86	-	1	Q37	0.958	$\alpha = 0.94$
D	8	Q42, Q43	0.94	0.96	0.83	-	1	Q8	0.922	$\alpha = 0.90$
S	8	Q13	0.93	0.94	0.79	-	1	Q15	0.909	$\alpha = 0.89$
I	4	Q34, Q49	0.94	0.95	0.75	-	1	Q32	0.955	$\alpha = 0.97$
$U=U_S+U_P$	9	Q29	0.92	0.94	0.83	0.94	2	Q67+Q45	0.945	$\omega_t = 0.95$
US	(6)		0.90	0.89	0.86	-	1	Q67	0.901 (0.849)	$\alpha = 0.87$ ($\omega_t = 0.77$)
UP	(3)		0.93	0.92	0.87	-	1	Q45	0.973 (0.820)	$\alpha = 1.02$ ($\omega_t = 0.72$)
$R=R_S+R_P$	18	Q47	0.90	0.93	0.68	0.92	4	$\frac{Q25+Q48+Q63}{3}+Q62$	0.910	$\omega_t = 0.90$
Rs	(7)		0.87	0.87	0.66	-	1	Q62	0.868 (0.723)	$\alpha = 0.87$ ($\omega_t = 0.57$)
Rp	(11)		0.86	0.90	0.63	0.91	3	Q48+Q26+Q63	0.895 (0.913)	$\omega_t = 0.88$ ($\omega_t = 0.91$)

Attitudinal Construct	Number of Items retained in Scale	Items rejected	Reliability of full scale				Dimensionality	Single-item Number	Single-item Correlation	Expected Reliability
			α	λ_6	β	ω_t				
R_{P1}	((4))		0.84	0.82	0.76	-	1	Q25	0.847 (0.753) ((0.681))	$\alpha = 0.85$ ($\omega_t = 0.62$) (($\omega_t = 0.50$))
R_{P2}	((3))		0.82	0.76	0.79	-	1	Q48	0.867 (0.620) ((0.606))	$\alpha = 0.92$ ($\omega_t = 0.42$) (($\omega_t = 0.40$))
R_{P3}	((4))		0.78	0.72	0.66	-	1	Q63	0.874 (0.731) ((0.682))	$\alpha = 0.98$ ($\omega_t = 0.59$) (($\omega_t = 0.51$))

Understanding each Attitudinal Construct

Analysis of student responses (Table 5.3)to the 68 items in the survey pool confirmed that four of the six ACs were unidimensional as intended and these are discussed here first. The ACs Usefulness (U) and Relevance (R) were found to be multidimensional and are discussed separately in the following sections.

Unidimensional Attitudinal Constructs

Intention (I) for future enrolment

A student's intention to enrol in a science course beyond the end of compulsory schooling might be considered to be a response to a positive general attitude towards the subject. The analysis of student responses shows that this AC appears to be a commonly understood concept for Year 7 students even though they have a further three years of schooling before having to make their enrolment decision. Two items—Q34 and Q49—were removed from the initial scale so as to improve the scale reliability resulting in a final internal consistency of the scale, as measured using coefficient alpha, of $\alpha = 0.94$. The dimensionality analysis and the comparison of coefficients lambda and alpha revealed a single, smooth dimension for this AC with the VAS LT item Q32 able to measure the construct with a single-item reliability estimate of $\alpha = 0.97$.

Enjoyableness (E)

A student's perception of the enjoyableness of school science appears to be a clear AC to Year 7 students. The scale reliability was again improved by the removal of two items—Q38 and Q36—from the original pool and resulted in a final internal consistency of $\alpha = 0.98$. Coefficient lambda is slightly greater than alpha, which suggests a small degree of ‘lumpiness’; however, the dimensionality analysis revealed a single dimension to this AC. The analysis suggests that the SD item Q37 ‘I think science is: Boring; Enjoyable’ is best able to measure the construct with a single-item reliability estimate of $\alpha = 0.94$.

As the selected item is of the SD format it is important to ensure that the end points of the scale represent a true dichotomy. The use of student focus groups to unpack the students' meaning in the word ‘boring’ revealed that students associated five words as suitable antonyms. As both the Year 7 and Year 10 focus groups identified ‘fun’ more clearly than ‘enjoyable’, the final item wording used was adjusted to reflect this.

Difficulty (D)

Perceived difficulty of a subject also appeared to be a well understood AC for Year 7 students. Two items—Q42 and Q43—were again removed from the scale to improve the reliability resulting in an overall internal consistency $\alpha = 0.94$. These two items also violated the assumptions for normality required for the use of parametric statistics ($W=0.98$, $p=.21$ and $W=0.99$, $p=.76$ respectively). The dimensionality analysis revealed a single, smooth dimension to this AC with the VAS LT item Q8 able to measure the construct with a single-item reliability estimate of $\alpha=0.90$.

Self-Efficacy (S)

A student's perception of their self-efficacy in a subject also seemed to be a very clear AC for Year 7 students. One item—Q13—was removed from the scale resulting in an overall internal consistency of the scale of $\alpha = 0.93$. One item—Q40—was found to violate the assumptions of normality required for the use of parametric statistics ($W=0.97$, $p=.12$) and so was also excluded from the scale. Comparison of coefficients *lambda* and *alpha* suggests a small degree of 'lumpiness' in the scale, yet the dimensionality analysis revealed a single dimension to the scale. The VAS LT item Q15 is best able to measure the construct with a single-item reliability estimate of $\alpha = 0.89$.

Usefulness (U) for future career.

Initial analysis of the full scale for usefulness revealed an internal consistency, measured using coefficient alpha of $\alpha=0.90$. Item Q29 'I would *dis*like a job in a science laboratory after I leave school' [emphasis not in original item] was rejected due to its much larger variance in response than other similar items, thus suggesting that it had been misread by a number of participants. This resulted in a full scale consistency of $\alpha = 0.92$. However, coefficient lambda was sufficiently larger than alpha to suggest a degree of lumpiness in the scale. Consideration of coefficient beta indicates that the worst-case reliability of the full scale is better than $\beta = 0.83$. The dimensional analysis of the full scale reveals two underlying dimensions; namely the usefulness of science for future careers in the science domain U_S and the usefulness of science for the participants' personal career choice U_P. The remaining nine items of the full scale could be distributed across these two sub-constructs (Table 5.4).

Table 5.4: Factor Pattern Matrix for Usefulness scale items

Items	F_1	F_2	h^2
Usefulness to science career items			
Q27. I would dislike being a scientist when I leave school	0.70	0.13	0.62
Q28. When I leave school, I would like to work with people who make discoveries in science	0.72	0.13	0.65
Q30. Working in a science laboratory would be an interesting way to earn a	0.86	-0.03	0.70
living	0.44	0.17	0.31
Q66. I would like to teach science when I leave school	0.89	0.00	0.80
Q67. A job as a scientist would be interesting	0.83	-0.11	0.58
Q68. A career in science would be dull and boring			
Usefulness to personal career items			
Q31. The science I learn at school will be very useful for my future career	0.34	0.60	0.72
Q44. For my future career, science will be: Optional ; Required	-0.02	0.95	0.88
Q45. For my planned career, knowledge of school science will be: Worthless ; Required	-0.01	1.00	0.99

Sub-Construct One – Usefulness (U_S) for Careers in Science.

Usefulness for careers in the science domain was best represented by the five-point, discreet LT item Q67 ‘A job as a scientist would be interesting’, with a single-item reliability estimate of $\alpha = 0.87$. This item could also be used to represent the general AC of Usefulness (U) with a reliability estimate of $\omega_t = 0.77$.

Sub-Construct Two – Usefulness (U_P) for Personal Career.

Usefulness for personal career choices was best represented by the VAS SD item Q45 ‘For my planned career, knowledge of school science will be: worthless; priceless’. This had a single-item reliability estimate of α=1.02. This overestimate is likely a consequence of only three highly-correlated items being assigned to this sub-construct. This item might also be used to represent the general AC of Usefulness (U) with a reliability estimate of ω_t=0.72.

As with the AC of perceived Enjoyableness (E), student focus groups were used to unpack the students' meaning in the word ‘priceless’, and this revealed that students associated a number of words as suitable antonyms. The Year 7 group identified five antonyms but showed no real preference for any one particular term. The Year 10 group identified just two antonyms and strongly focussed on the word ‘worthless’. The final item wording was therefore retained as per the original item.

Estimating for the General Usefulness (U) Attitudinal Construct.

Combining the scores for sub-constructs US and UP as an unweighted average gives a measure that is able to estimate a participant's perception of the usefulness of school science for their future career. As Usefulness (U) has an underlying structure and is multidimensional, alpha does not yield a valid estimate of reliability. Consequently coefficient omega (McDonald, 1999) was calculated, $\omega_t = 0.94$, as a more robust measurement of the reliability of this scale (Starkweather, 2012). This gives an estimation of the reliability of measuring the Usefulness (U) AC with the unweighted average of $\omega_t = 0.95$.

Relevance (R) for everyday life

The analysis of the Relevance (R) AC showed an initial internal consistency, measured by coefficient alpha, of $\alpha=0.90$. Removal of the negatively correlating item Q47 resulted in no change to the internal consistency but allowed the analysis to be interpreted. Comparison with coefficient *lambda* suggested that this full scale has significant lumpiness. A hierarchical cluster analysis (Table 5.5) revealed two primary clusters of items which are described as the Relevance of science to society, R_S, and Personal relevance of school science, R_P . The analysis process was applied to these sub-constructs.

Sub-Construct One - Relevance (R_S) to Society.

Analysis of the relevance to society items, revealed that it is a mostly unidimensional construct and might be best described as 'science as a human endeavour'. The internal consistency of this sub-group of items was calculated as $\alpha=0.87$. The five-point discreet LT item Q62 'Science helps to make life better' was the best measure of the sub-factor with a single-item reliability estimate of $\alpha=0.87$. This item may also be used to estimate the general construct of relevance with a reliability estimate of $\omega_t=0.67$.

Sub-Construct Two - Personal Relevance (R_P) of School Science.

Analysis of the personal relevance of school science revealed a further three underlying dimensions. The first dimension can be described as a personal desire to learn about the science of the natural world. Dimension two appears to represent the applicability of school science to everyday situations. The third dimension may be described as a student's desire to understand the technologies utilised in the everyday world. The eleven items in this scale were distributed to three sub-groups (Table 5.5) representing these dimensions.

Table 5.5: Factor Pattern Matrix for Relevance scale items

Items	F_1	F_2	F_3	F_4	h^2
Relevance of science to society items					
Q17	0.71	0.04	0.09	-0.06	0.57
Q18	0.50	0.04	0.09	-0.17	0.27
Q19	0.49	0.17	0.18	-0.03	0.44
Q20	0.55	-0.01	0.12	-0.03	0.36
Q60	0.71	-0.07	-0.05	0.09	0.50
Q61	0.84	-0.05	-0.08	0.10	0.69
Q62	0.85	0.06	0.03	-0.01	0.77
Personal relevance of school science – understanding the natural world.	-0.05	0.69	-0.08	-0.24	0.60
Q22	0.12	0.56	-0.22	0.31	0.55
Q23	0.06	0.83	0.01	-0.16	0.65
Q24	0.01	0.78	0.20	0.00	0.74
Q25					
Personal relevance of school science – applicability od school science	0.24	0.29	0.06	0.44	0.44
Q21	0.02	0.07	0.22	0.66	0.63
Q63	0.12	-0.06	0.09	0.73	0.63
Q64	0.09	0.17	-0.02	0.48	0.36
Q65					
Personal relevance of school science – understanding everyday technologies	0.15	-0.02	0.72	0.01	0.63
Q26	-0.06	0.04	0.64	0.23	0.53
Q46	0.04	0.06	0.78	0.03	0.68
Q48					

Dimension one was best represented by VAS LT item Q25 'I want to learn about plants in my area' with a single-item reliability estimate of α=0.84. The variation in correlation across the items of this dimension was very low and it is reasonable therefore to merge the wording of this item with that of Q24 to broaden the scope of this dimension. This item may also be used to represent the sub-factor personal relevance (R_P) with a reliability estimate of ω_t=0.62 or the general factor of Relevance (R) with a reliability estimate of ω_t=0.50.

Dimension two was best represented by the VAS item Q48 'For my everyday life, I think that school science is: irrelevant; relevant' with a single-item reliability estimate of

α=0.92. This item might also be used to represent the sub-factor personal relevance (R_P)with a reliability estimate of ω_t=0.42 or the general factor of relevance (R) with a reliability estimate of ω_t=0.40.

Dimension three was best represented by five-point discreet LT item Q63 ‘I want to learn about electricity and how it is used in the home’ with a single-item reliability estimate of α=0.98. This item could also be used to represent the sub-factor personal relevance with a reliability estimate of ω_t=0.59 or the general factor relevance with a reliability estimate of ω_t=0.51.

Combining items Q25, Q48 and Q63 as an unweighted average gives a measure that is able to estimate a participant's perception of the personal relevance of school science. As personal relevance has an underlying structure, alpha will not yield a valid estimate of reliability. *Omega*, ω_t=0.88, was calculated as a more robust measurement of the reliability of this sub-construct. This gives an estimation of the reliability of measuring the full Relevance (R) AC using this combination of ω_t=0.91.

Estimating for the General Relevance (R) Attitudinal Construct.

Relevance (R) of science for career is clearly a very multifaceted concept and some caution is advised in drawing conclusions about this AC. Combining the scores for personal relevance of school science (R_P) and relevance of science to society (R_S) as an unweighted average gives a measure that is able to estimate a participant's perception of the general relevance of school science. The internal reliability of the full AC as measured using *omega* is ω_t=0.94. This gives an estimated reliability of ω_t=0.95.

Generalisation to different school contexts.

It is important that the SSAS can measure attitudes equally well for regional, rural, remote and metropolitan school students as well as for male and female students. We therefore hypothesise that there should be no significant difference between the way these participant-groups interpret the items in the instrument. That is to say, while there are many factors such as socio-economic status, cultural background, student sex, education system that could affect a student’s attitude scores, their response to the selected single-items should not be statistically different from their mean score for the corresponding multi-item scale. We will refer to this difference between single-item score and mean multi-item score as the score-variance (SV).

Following the single-item selection procedure outlined in the previous section, a two factor analysis of variance (ANOVA) was conducted between the SV and the factors participant-sex and school-location. The model also included an interaction term for completeness. We decided that items with $p<.05$ would be deemed to show significant variance between population groups and should result in the null hypothesis being rejected. Items with $.05\leq p<.10$ were deemed to infer borderline significance—which may or may not be significant with a larger sample group—and should be taken into consideration in any future analyses based upon this instrument. This conservative approach was adopted so as to minimise type I errors. The overall results of these analyses are shown in Table 5.6

No significant interactions between participant-sex or school-location were identified in the interpretation of items for any AC except for Usefulness for Personal Career (U_P) ($p=.050$). The analysis for this sub-construct showed that the interaction of participant-sex and school-location had a borderline significance on the way students interpreted item Q45, 'For my planned career, knowledge of school science will be: worthless; required' compared to the other two items in this sub-scale. The analysis shows that male students in regional schools underscored themselves on this item in relation to the other items of the sub-construct by around 14 points. This is significantly different ($t(110)=1.982$, $p=.050$) from male students in metropolitan schools and female students in any setting. However, as this interaction is a borderline effect and the item pool is small, we do not believe the rejection of the null hypothesis is fully justified for this AC.

As we are unable to reject the null hypothesis for any single-item AC, we draw the conclusion that the items selected for use in the SSAS are understood and interpretable equally well by both male and female students in metropolitan, regional and rural schools. This instrument, and its resulting data, are therefore transferable across these different schooling contexts.

Table 5.6: F-values resulting from the two-way ANOVA tests for the effects of participant sex, participant location and the interaction on the Attitudinal Constructs Enjoyableness, Intentions to Enrol, Self-Efficacy and Difficulty.

Attitudinal Construct	Effects	df	F	p
Intentions to Enrol (I)	Sex	1,114	1.19	.277
	Location	2,113	0.87	ns
	Sex:location	1,110	0.00	ns
Enjoyableness (E)	Sex	1,114	0.64	ns
	Location	2,113	0.37	ns
	Sex:location	1,110	0.06	ns
Self-Efficacy (S)	Sex	1,114	0.00	ns
	Location	2,113	0.36	ns
	Sex:location	1,110	0.08	ns
Difficulty (D)	Sex	1,114	1.46	.229
	Location	2,113	1.74	.180
	Sex:location	1,110	0.71	ns
Usefulness for Personal Careers (UP)	Sex	1,114	1.07	.304
	Location	2,113	2.10	.127
	Sex:location	1,110	3.93	.050 *
Usefulness for Science Careers (US)	Sex	1,114	1.01	.317
	Location	2,113	1.09	.339
	Sex:location	1,110	0.92	ns
Relevance to Society (RS)	Sex	1,114	0.04	ns
	Location	2,113	0.09	ns
	Sex:location	1,110	0.01	ns
Personal Relevance Dimension 1 (R_{P1})	Sex	1,114	0.11	ns
	Location	2,113	0.20	ns
	Sex:location	1,110	0.00	ns
Personal Relevance Dimension 2 (R_{P2})	Sex	1,114	0.38	ns
	Location	2,113	1.52	.224
	Sex:location	1,110	0.74	ns
Personal Relevance Dimension 3 (R_{P3})	Sex	1,114	0.97	ns
	Location	2,113	1.18	.311
	Sex:location	1,110	0.04	ns

Discussion

This study set out to answer two questions:

1) can a single instrument be developed to measure multiple facets of a student's attitude towards school science?

2) can student attitudes towards school science be reliably measured in a time-efficient manner using single-item measures?

Our analysis has shown that of the six constructs that we attempted to measure, the Personal Relevance (R_P) of school science is the most difficult aspect to assess and is likely to be the least transferable to other domains. Whilst not disregarding this sub-construct from the Attitude Profile (AP), we suggest that in narrowly focussed studies, future researchers, who desire to understand only the effects of personal relevance, may be advised to select one of the more specific instruments outlined in Table 5.1.

Discussions with the Year 7 focus group also make it apparent that there may be inherent problems with measuring the usefulness for a planned career (U_P) with 12 and 13 year-olds. It seems likely that students may have one or more very broad career paths in mind at this age and so could struggle to see direct usefulness for their school science. However, the discussions with the Year 10 focus group makes it clear that this construct becomes more influential with age and so it was retained in the AP.

Throughout the analysis process a higher standard of reliability (*alpha* or *omega* greater than 0.90) has been adopted than the 0.80 recommended by Wanous and Hudy (2001). In examining the effects of participant-sex and school-location on the generalisability of items between school contexts using ANOVA, a more conservative threshold of $p<.10$ was adopted that the usual $p<.05$. Under these conditions, single-item measures have been shown to yield reliable, valid and transferable data. We have also shown that the combination of a web-based tool and VAS items together allow the robust and reliable use of these single-item measures to measure ACs. The use of ten single-items to describe a student's AP for a school subject not only allows for time-efficient measures to be made but opens up opportunities to extend this measurement approach across multiple subject areas, or longitudinally over time, without becoming burdensome to participants or researchers.

Although the SSAS instrument has been designed for use as a long-term longitudinal profile tool, it has the potential to be used effectively in a number of other scenarios. The SSAS can be readily used to provide one-off snapshot data or to provide pre- and post-test comparison data to investigate the effect of a particular intervention strategy. The data collected through the SSAS could be usefully visualised in a number of modes—the most appropriate format being tailored by the specific research question—but radar plots, box-plot-profiles (Figure 5.4), or matrices of time-series boxplots could be informative to researchers.

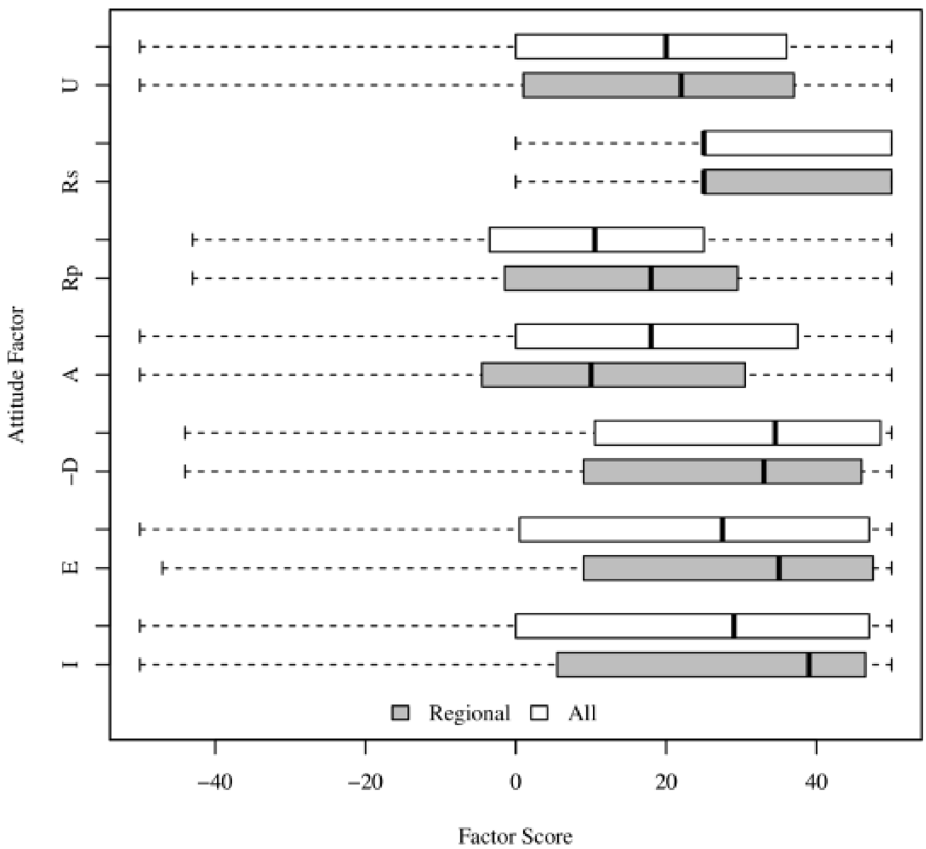

Figure 5.4: Boxplot analysis of Science Attitudinal Profile of students in regional schools (shaded) compared with the full sample.

In keeping with convention, the dark centre line indicates the median, and the whiskers 1.5 times the inter-quartile range.

However, the use of the SSAS is necessarily limited to the school science domain as the initial pool of questions was selected so as to ascertain a student's attitude towards very specific areas identified in the literature. In order to generalise the instrument to the whole breadth of the curriculum, the processes outlined in this paper would need to be repeated for other KLAs. It should also be noted that the SSAS has been designed to determine what a group of students' attitudes are towards science and how they change. It is not intended to explain why a particular student holds specific attitudes nor is it designed to indicate causality between the various ACs of a student's AP.

Conclusions

In this paper we have demonstrated that it is possible to reliably and validly assess student attitudes towards school science using a simple and efficient instrument. Starting from a model of an Attitudinal Profile constructed of six Attitudinal Constructs—Enjoyableness, Self-Efficacy, Difficulty, Usefulness for career, Relevance for everyday life, and Intention to enrol—and a pool of 68 items based on four well established instruments, we have shown that it is possible to measure these Attitudinal Constructs using just ten single-item measures. Furthermore, the analysis shows that the use of these single-items can be as reliable as multiple-item scales in this context, particularly when combined with Visual Analogue Scales.

Although we note that the scope of this instrument is limited to the school science domain, examination of the final items included in the SSAS suggests that it should be relatively straightforward to repeat this analysis procedure and develop similar items for other subject areas thence creating a more general school attitude survey. Such a general instrument could have particular application in longitudinal studies of attitudes as it would not be too 'bloated' and would likely reduce the effects of survey apathy on response quality.

The process outlined in this article, and in particular the instrument described herein, also offers the potential to provide a 'does it work?' critique of some educational interventions aimed at improving attitudes towards school science. The analysis and comparison of data gathered using this instrument pre and post intervention, could offer educators, researchers and policy makers alike the opportunity to determine which initiatives are likely to work to address student attitudes in particular school contexts and provide the basis for a common language for change in schools.

5.4 Statement of authors' contribution

We, the PhD candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in this thesis and they have accepted the candidate's contribution as indicated in the Statement of Originality.

	Author's Name	% of contribution
Candidate	JohnPaul Kennedy	80
Other Authors	Dr Frances Quinn	10
	Professor Neil Taylor	10

[redacted]

JohnPaul Kennedy
(Candidate)

25th September 2018

[redacted]

Dr Frances Quinn
(Principal Supervisor)

25th September 2018

5.5 Statement of originality

We, the PhD candidate and the candidate's Principal Supervisor, certify that the following text, figures and diagrams are the candidate's original work.

Type of Work	Page Number/s
Figure 5.1	106
Figure 5.2	110
Figure 5.3	113
Figure 5.4	126

[redacted]
JohnPaul Kennedy
(Candidate)
25th September 2018

[redacted]
Dr Frances Quinn
(Principal Supervisor)
25th September 2018

Chapter 6: The Keys to STEM: Australian Year 7 Students' Attitudes and Intentions Towards Science, Mathematics and Technology Courses

6.1 Introduction

Chapter 1 established two research themes (p. 5) for this thesis. In Chapter 3 and Chapter 4 I explored the current state of student participation rates in the STEM disciplines in Australian high-schools. A commonly accepted mechanism within the STEM education field is that students who possess positive attitudes towards the STEM subjects are more likely to enrol in STEM courses at the high-school level or beyond. However, as noted in Chapter 2, while this link seems reasonable, the link has not been definitively proven. In order to delve into understanding the influence of students' attitudinal constructs on their intentions to enrol in particular STEM disciplines in post-compulsory education, it is essential that students' attitudes be measured and monitored over time.

The article presented in this chapter makes use of a generalised version of the School Science Attitudes Survey discussed in Chapter 5. The data analysed are critical in developing answers to research questions RQ6 and RQ7. In particular, the longitudinal study of the same cohort of students, all of whom were undertaking their first year of high-school, in numerous schools across New South Wales is able to begin to reveal the extent and nature of the development of and changes in student attitudes towards STEM subjects (RQ7).

The article first places my research into the context of measuring students' attitudes towards STEM subjects at school by considering the summary reviews of a number of researchers and their findings (e.g., Aiken, 1970; Osborne, Simon, & Collins, 2003; Osborne, Simon, & Tytler, 2009; Potvin & Hasni, 2014; Simpson & Oliver, 1990). I then argue that while the theory of reasoned action (Fishbein & Ajzen, 2011) appears suitable for explaining the link between students' attitudes and their enrolment intentions the resulting correlation between these constructs requires further investigation. Of particular relevance in understanding these predicted correlations is the effect of time; to what extend do students' attitudes change over time. Analysis of the literature is strongly suggestive of the idea that attitudinal constructs are not fixed but that they can change either steadily or suddenly in relation to events and experiences. I conclude therefore that there is a gap in the research corpus for an longitudinal cohort study of the nature presented in this article.

The article develops the concepts of Subject Attitude Profiles and Composite Attitude Profiles that I proposed in Chapter 5 (p. 126) and uses this approach to compare the attitude profiles of different groups of students at the end of semester 1 and semester 2 of their first year of high school. This unique methodology allows for the attitudes of groups of student towards individual STEM subjects to be measured and compared in relation to their composite attitude ratings for all of their school subjects. As a result, this approach is capable of identifying whether a change in a student's reported attitudes is due to a change in their attitudes towards a particular subject, for example science, or towards their school subjects in general. This unique type of insight is not available through other existing approaches.

The resulting graphical profiles show that students generally have fairly positive attitudes towards their school subjects in general which decline slightly over the course of the first year. In comparison, students to begin with report science and mathematics as being more difficult and less enjoyable than their school subjects in general with mathematics being further from the composite ratings. Attitudinal constructs towards technologies on the other hand tend to be reported much more favourably; at least in semester 1. Finally, the article discusses how these Subject Attitude Profiles change over the year and suggests some areas for further inquiry in the search for student explanations

6.2 Journal Article 4

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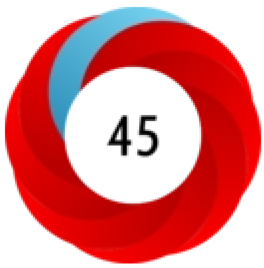
6.3 Article Impact

At the time of submission of this thesis, this article had been the subject of a story in The Sydney Morning Herald (Singhal,



2018a, 2018b) and had been syndicated in four other national newspapers and online. The article has received an Almetric Attention Score of 45 placing it “in the top 5% of all research outputs scored by Altmetric” and “One of the highest-scoring outputs from this source (#3 of 342)”.

The Keys to STEM: Australian Year 7 Students' Attitudes and Intentions Towards Science, Mathematics and Technology Courses

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Educational researchers have long noted the apparent link between positive student attitudes and a student's desire to continue their study of particular subjects beyond the compulsory years of schooling, with much of the research motivated by concerns around declining student participation rates in high-school and university. However, unambiguously measuring students attitudes is notoriously difficult. In addition, the question of which attitudes have the most significant effect on student intentions is not fully understood. This study was designed to address the gap in understanding between students' attitudes and their enrolment intentions by surveying a large cohort of Australian students at regular intervals during their first year of high-school (Year 7, aged 12-13 years). An innovative, new digital instrument was used to gather quantitative data about students' attitudes towards school subjects across seven constructs. Subject Attitude Profiles were then constructed for the disciplines of science, mathematics and technologies and compared with each other and also with a Composite Attitude Profile for all school courses. We show that although students' attitudes to the STEM subjects vary widely, their attitudes generally decline over the first year of high-school with regards to a number of attitudinal constructs. We also show that the trends within these STEM disciplines are not identical and we therefore conclude that each discipline requires a individual responses if students' attitudes are to be addressed.

Introduction

Since the 1970s an impressive corpus of research literature has accumulated around the study of young peoples' attitudes to school science and mathematics, including regular systematic reviews (e.g., Aiken, 1970; Bennett, Braund, & Sharpe, 2013; Blalock et al., 2008; P. L. Gardner, 1975; Haladyna & Shaughnessy, 1982; Leder, 1987; Osborne, Simon, & Collins, 2003; Osborne, Simon, & Tytler, 2009; Potvin & Hasni, 2014b; Ramsden, 1998; Simon & Osborne, 2010; Simpson & Oliver, 1990). Much of this research has been motivated by concerns about declining rates of participation in science, mathematics—and more recently—digital technology subjects at the upper high-school and tertiary levels (e.g., Dekkers & de Laeter, 2001; Forgasz, 2006; Kennedy, Lyons, & Quinn, 2014; Kennedy, Quinn, & Lyons, 2018; E. Smith, 2011). These negative trends have generated a great deal of discussion in the media (e.g., D. Smith, 2011; Tisdell, 2014) and in political/economic publications (e.g., Deloitte Access Economics, 2014; Education Council, 2015; Lowe, 2014; Prinsley & Baranyai, 2015) in Australia. In these and related reports, STEM-focussed educational pathways have been posited as a solution to numerous problems facing Australia's productivity into the future; from a method of securing Australia's scientific and economic sustainability post mining-boom (e.g., Commonwealth of Australia, 2015; Lowe, 2014; Office of the Chief Scientist, 2013) to enabling informed citizens to interact effectively with their world (Australian Curriculum and Assessment Reporting Authority [ACARA], 2016).

The assumption that declining enrolments in post-compulsory science and mathematics are due in part to declines in attitudes to these subjects in early high-school is implicit in many initiatives to improve both. The rationale appears to be that, if we can understand what hinders students from forming a positive outlook towards these subject areas, then suitable interventions can be designed and implemented to address these attitudes and thereby begin to reverse the current declining trends in student participation. This premise is apparent in the burgeoning number of STEM outreach programmes offered by universities and other stakeholder organisations across Australia. The STEM Programme Index 2016 (Office of the Chief Scientist, 2016), for example, lists over 250 programmes available to students with further initiatives available to teachers.

However, research evidence for a direct causal link between attitudes and intention to participate in science and mathematics courses has proven to be elusive. While the systematic reviews (e.g., Potvin & Hasni, 2014b) and large scale international comparisons (e.g., Kjærnsli & Lie, 2011) tend to concur that attitudes have a substantial influence on young peoples' future study or career orientation, they nevertheless acknowledge that more —or different—research is needed to clarify the nature and mechanisms of this influence.

This paper presents early findings from an innovative longitudinal study which monitored student attitudes towards all their academic subjects over the first four years of high-school. The findings presented here focus on the changing attitudes towards science, mathematics and technologies courses—individually and relative to other subjects— recorded by 363 students in New South Wales during their first year of high-school. Through the use of a novel instrument yielding longitudinal, subject-specific and broad data across multiple attitudinal constructs, allowing us to explore and follow the early changing attitudes of students towards individual STEM subjects against the backdrop of attitudes to school subjects in general. In addition, these early findings validate the longitudinal approach to studying attitudes adopted in this research.

Defining attitudes

One of the complications in exploring the nexus between student attitudes to, and enrolments in, the STEM subjects is that, as noted by most of the systematic reviews, operational definitions of *attitudes* across studies vary substantially from narrow to broad, and often reflect different ontologies. As argued by Simon and Osborne (2010, p. 239), research into the area of attitudes has been “bedevilled by a lack of clarity about what attitudes to science are”, a sentiment which no doubt applies to studies in other subject areas. Moreover, many previous studies have tended to identify attitudes towards school science or mathematics, attitudes towards science or mathematics in general, and scientific and mathematical attitudes or approaches as separate concepts. The potential for generalisation of the findings has therefore often been limited due to these variable definitions of *attitude*. Kind, Jones and Barmby (2007, p. 873) attempted to address this confusion, and define an attitude as “the feelings that a person has about an object, based on their beliefs about that object”. This definition of attitudes was also adopted in this study, where in the context of school STEM courses, the *object* is considered to be the course of study for the student.

Attitudes are also multifaceted. However, many studies on attitudes towards school STEM subjects have identified a number of constructs in common (e.g., Archer et al., 2010; Barmby, Kind, & Jones, 2008; Fraser, 1982; Fraser, Aldridge, & Adolphe, 2010; Holmegaard, Madsen, & Ulriksen, 2014; Lyons, 2006; Lyons & Quinn, 2010; Osborne et al., 2009). These attitudinal constructs relate to enjoyment of the subject, perceived relevance of the subject, students’ past successes and achievements in the subject, and the anticipated benefits from studying the subject. Similarly, numerous factors have been identified as impacting the formation of these positive student attitudes including effective teaching, student gender, and perceptions of course difficulty in comparison with the academic benefits to be gained (e.g., Archer et al., 2010; Barmby et al., 2008; Barnes, McInerney, & Marsh, 2005; Carter, 2006; Chinnappan, Dinham, Herrington, & Scott, 2008; Holmegaard et al., 2014; Lyons & Quinn, 2010).

In exploring the nexus between attitudes and enrolment decisions, the reasoned action approach to understanding behaviours described by Fishbein and Ajzen (2011) has potential for traction. This approach supposes that a person's intentions towards an object follow in a consistent and reasonable manner from their attitudes towards that same object. Note that Fishbein's and Ajzen's approach does not require that the action be rational nor deeply deliberated before being performed (2011, p. 24); spontaneous and automatic responses based on previously formed attitudinal foundations can be still be considered to be reasoned action. Based on this approach, it is reasonable to expect that students' enrolment decisions might be based at least in part on the attitudes they hold. Hence, understanding the formation of student attitudes may provide further insight into some reasons for the declining rates of student participation in some STEM subjects across Australian schools that have been tracked by Kennedy et al. (2014, 2018).

The relationship between declining attitudes and enrolments

Discussions about attitudes and enrolment intentions are sometimes muddied by differing interpretations about what is meant by *declining attitudes* and which methodologies have been employed to investigate these. Cross-sectional comparison studies, for example, typically compare attitudes reported by similar age-cohorts at different times. For instance, the Programme for International Student Assessment (PISA) surveys the attitudes towards mathematics of 15 year-old students every nine years. Longitudinal studies, on the other hand, tend to examine changes in attitudes among the same students as they progress through school or transition from primary to secondary school (e.g., Logan & Skamp, 2008).

Attitude data from the two types of studies provide different insights into students' intentions or enrolments, though no conclusive evidence of an association. With respect to cross-sectional comparisons studies, the assumption that attitudes (variably defined) to school science and mathematics have in fact declined over time with enrolments is problematic. For instance, the most recent PISA study concluded that Australian students' enjoyment of learning science increased significantly between 2006 and 2015 (OECD, 2016, p. 123). In contrast however, Year 12 participation rates in physics, chemistry and biology actually declined between 2006 and 2012 (Kennedy et al., 2014). Moreover, Lyons and Quinn ((2010)) compared two data sets collected 30 years apart using the same instrument (Fraser, 1982) with comparable schools and samples in metropolitan Sydney.

They found no meaningful differences between the two cohorts in terms of their attitudes to science , despite dramatic declines in enrolment rates across the intervening decades.

With regard to longitudinal studies, a number of international and Australian studies (e.g., Ormerod & Duckworth, 1975; Speering & Rennie, 1996; Whitfield, 1979) have reported steady declines in attitudes towards science and mathematics as pupils transition to, or progress through, early high-school. A review of 21 international studies by Potvin and Hasni (2014a) concluded that the evidence strongly supports a general decline in attitudes to science and technology subjects as school progresses. They canvass a range of plausible explanations for this trend, including increasing subject difficulty, a greater focus on examinations, and students' evolving identities and personal priorities, recognising that "it is very difficult to see if the observed decline is attributable to the school S&T experience in particular or to the more general school experience" (2014a, p. 788). This is one of the challenges addressed by the study reported here.

Rationale

Given the lack of clarity surrounding some of these issues apparent in our analysis of the research literature, the study reported here takes a novel approach to addressing a number of methodological impediments to further progress in this field.

First, most studies have focused on changes in students' attitudes towards individual subjects without considering changes in attitudes to school more generally, and whether these may also have changed. This contextual information is important in establishing whether, for example, a reported decline in attitudes to science over several years signals a problem with school science, or reflects a decline in attitudes towards school more generally. The present study surveys students' attitudes to *all* their school subjects including individual STEM subjects. This approach enables a measure of student attitudes to school subjects overall, as a point of reference against which to assess attitudes specifically in relation to science, mathematics and technologies.

Second, the majority of attitude studies have been cross-sectional, either surveying a single age cohort at a point in time, or surveying different age cohorts and drawing conclusions about differences (e.g., Thomson, Wernert, O'Grady, & Rodrigues, 2017). In contrast, there have been few studies, especially in Australia, designed to follow a sizeable cohort of students and map changing attitudes over time. Given the concerns about attitude declines during the lower secondary years (Osborne et al., 2003; Speering &

Rennie, 1996) and the limitations of cross-sectional designs, there is clearly a need for a longitudinal cohort study.

Third, there is an increasing tendency in the media and policy documents to use the convenient umbrella term ‘STEM’ when discussing engagement and participation, without fully distinguishing between these subjects (Education Council, 2015 (i.e., STEM Strategy)). The present study was designed to differentiate between attitudes to science, mathematics and technology subjects, in order to identify similarities and differences that may be important in understanding student responses to these subjects.

Finally, in contrast to the science and mathematics education literature, there are far fewer studies documenting high-school students’ attitudes towards the technology and engineering disciplines. In a number of the studies focussing on the technology aspect of STEM, technology itself is often not cast primarily as a knowledge domain but rather as a toolbox of skills that can be applied to other areas. This has even lead some researchers to question whether it is only the areas of science and mathematics that are of interest rather than STEM as a whole (Lederman & Lederman, 2013). Hence this study includes a focus on technology.

In summary, the study presented here was designed to address some of the gaps in the research literature about attitudes to school science, mathematics and technology by surveying a large cohort of students at regular intervals about a range of attitudinal constructs across a variety of subjects, including science, mathematics and technology, as they progressed through their first year of high-school. This paper focuses on early changes in students’ attitudes towards these three subject areas against a backdrop of their attitudes to school subjects more generally.

Research Questions

In its focus on students’ attitudes towards *school* science, mathematics and technology courses in relation to other subjects and its longitudinal approach to quantitative data collection, this study attempts to fill in some of the gaps in the existing research corpus. Specifically this article addresses the following research questions:

1. How do students’ attitudes towards STEM subjects compare to their attitudes to school in general as they begin high-school?
2. Are there any differences in the attitude profiles of male and female students?

3. Which attitudinal constructs have the strongest association with a student's *intention* to continue with a STEM-focussed education?
4. How fixed are students' attitudes towards STEM subjects over the first year of high-school?

Methodology

This study is situated within a post-positivist paradigm, using a psychometric approach to investigate different attitudinal constructs. The research questions were addressed through adoption of a longitudinal study design, using a web-based survey instrument—the School Science Attitude Survey [SSAS] (Kennedy, Quinn, & Taylor, 2016)—to investigate students' attitudes to school subjects over time. Within the Australian education system the start of high-school marks the point where the majority of students begin to experience science, mathematics and technologies as separate specialist learning disciplines. Due to the significance of this transition in students' lives, and the breadth of the data collected, this article focuses on the changes in attitudes of these students towards the STEM disciplines only during this first year of high-school. The study was undertaken between 2014 and 2017.

The Instrument

The SSAS is designed to merge attitudinal measurements with the preference ranking techniques developed by Whitfield (1979)—which tried to answer the question 'how does the popularity of science change over time compared to other school courses'? The development and validation of the SSAS instrument by the first author is detailed in Kennedy et al. (2016). The instrument captures a student's responses to items associated with seven attitudinal constructs across all of his or her various school subjects at regular times during the first two years of high-school. The instrument was specifically designed to be accessible to students through any web browser on a computer, tablet or smart-phone device irrespective of operating system. These attitudinal constructs are enjoyability [E], self-efficacy [SE], perceived difficulty [D], usefulness for my personal career [U_P], usefulness for a specific career in that domain [U_s], relevance to society [R], and intention to continue with study beyond compulsory education [I].

The instrument's design allowed for longitudinal data to be collected for each of these attitudinal constructs across a range of subjects. This approach allows attitude profiles [AP]—visual and numerical representations of the seven attitudinal constructs—to be created for individuals or groups of students, and for single subjects or clusters of subjects. An attitudinal profile for a single subject area will be referred to as a subject attitude profile [SAP]. The instrument can also yield a composite attitude profile [CAP] for students towards their school subjects in general (see generation of attitude profiles for further explanation). The CAP is then able to act a baseline reference point against which individual SAPs may be compared.

Previous attempts to measure students' attitudes towards school subjects have utilised data collection methods that focus either narrowly on the subject of interest (e.g., Ardies, De Maeyer, Gijbels, & van Keulen, 2015; Barmby et al., 2008; Blackweir, 2016; Gable & Roberts, 1983) or broadly on student attitudes towards school in general (e.g., Abu-Hilal, 2000; Khoo & Ainley, 2005). Primarily this limitation of scope has tended to be a necessary consequence of the instruments used and the result of attempts to avoid survey apathy or other undesirable influences. However, these approaches have inadvertently resulted in findings that are not readily comparable between areas of study or transferable between student contexts. The CAP approach utilised here addresses some of these issues by calculating each student's reported attitude ratings towards each subject relative to their mean attitude rating for all subjects within each attitudinal construct (detailed further below). This allows the findings from each subject area to be readily compared and at the same time minimises the impact of extraneous non-academic influences on general attitudes such as the school social environment or friendship groups.

Participants

Over 300 schools were invited via e-mail to be a part of the sample group from across all three educational sectors and from all areas of New South Wales [NSW]. Due to various commitments by schools an opportunity sampling process was adopted, and in total 363 students who were in their first year of high-school (Year 7, age 12-13 years) at the outset of their participation provided the data used in this analysis. The students were drawn from 19 schools across NSW. These comprised 17 independent schools, one Catholic systemic school and one government school. Of these, seven were single-sex schools and twelve were co-educational schools. Thirteen schools were located in the Sydney metropolitan area, four in regional centres and two in rural settings. All students were studying the STEM disciplines as separate school subjects.

Data Collection Procedures

Students were invited via e-mail to access the instrument once per term (i.e. four times a year) throughout Year 7 and were tracked between sample-times using a unique random identifier, thereby permitting longitudinal as well as cross-sectional analysis of the gathered data. On first login, the tool was customised by the student so that only subjects they studied were included in the subsequent screens. Additional demographic data were also captured at this time, such as gender, broad parental occupation and education, school location and so forth for use with later group level analyses. An example of the interface presented is shown in Figure 6.1. Students rated each of their school subjects using visual analogue scales (transparently digitised to a score from -50 to +50) with semantic differential endpoints for each of the seven attitudinal constructs. Each input screen presented only a single attitudinal construct to students at a time while providing sliders to collect data for all of their school subjects on the same page. Students were therefore able to naturally rate their subjects relative to each other. For the first round of data collection all scales were initialised to a value of zero. For the second and subsequent rounds of data collection, each scale for each subject was initialised to the student's previous rating. Therefore, students only needed to change those ratings for the scales which they felt had changed for them over the intervening time period, thus preserving the continuity of the longitudinal data. In addition to the quantitative data collected, the instrument also offered —but did not require—students the opportunity to add clarifying qualitative data explaining their change in attitude.

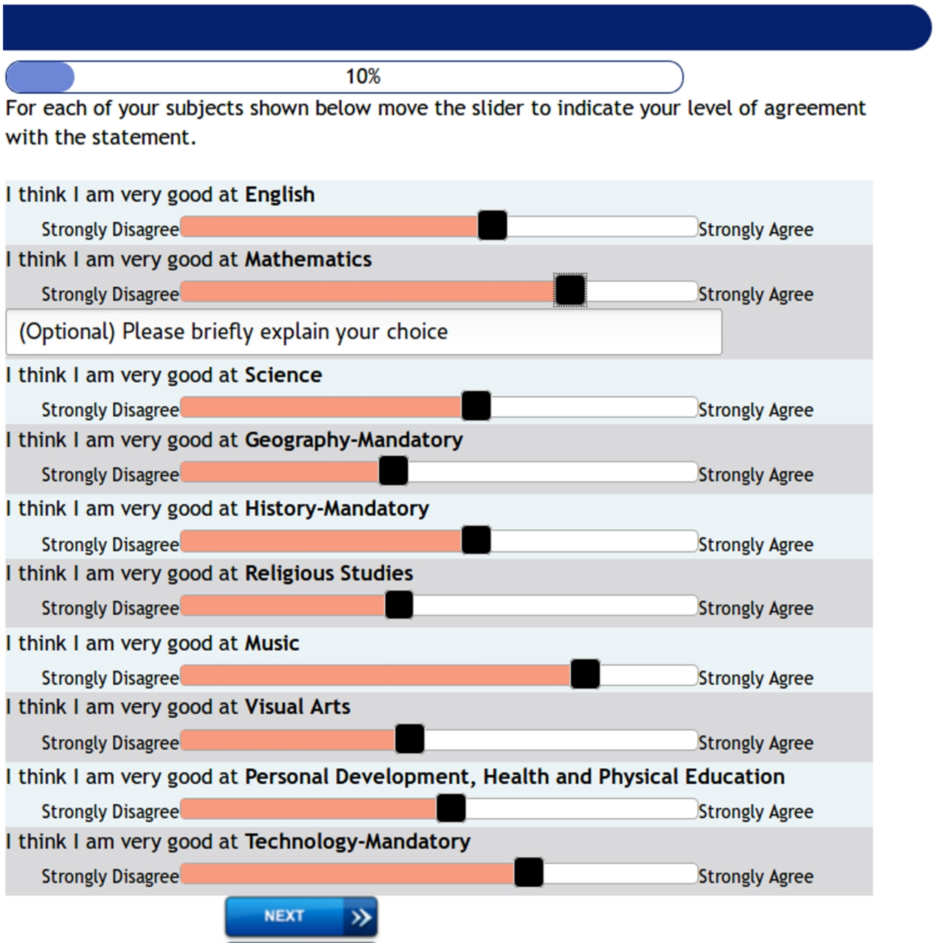

Figure 6.1: Screenshot of one of the data entry screens of the collection instrument as experienced by students.

Note that slider positions are initialised with the student's previous scores—or at the centre point if the student is a new participant—and that when a slider is moved by more than a pre-set amount—mathematics in this case—a text box appears so as to capture qualitative explanations.

As discussed in Kennedy et al. (2016), the use of single-item measures to capture a student's attitudinal beliefs is not without controversy (e.g., D. G. Gardner, Cummings, Dunham, & Pierce, 1998; Oshagbemi, 1999; Wanous & Hudy, 2001). However, through the adoption of a thorough analytical approach to item selection, together with the imposition of requirements for very strong internal validity and consistency, we were able to demonstrate that in the context of student attitudes the use of visual analogue scales combined with the digital instrument provided reliable and robust data for analysis.

Data Analysis: Generation of attitude profiles

The SSAS instrument records a student's raw rating from -50 to +50 in response to the position of the slider on the visual analogue scale. This raw attitude rating *(x)* is recorded for each individual student *(i)*, for each school subject *(S)*, and for each attitudinal construct *(A)* at a particular point in time *(t)*. The raw attitude rating is thus denoted as x_{iSAt}.

A student's collective ratings towards their school subjects at a point in time comprises what we refer to as a student's full Attitudinal Profile [AP], noting that the *profile* is not fixed but labile and context dependent. An AP is a visual representation of the attitude ratings for a single participant and is best understood in the form of a bar chart (Figure 6.2). An AP can also be constructed for a defined group of students for all attitudinal constructs at a point in time. In this situation, the AP is best represented as a boxplot centred around the mean for each attitudinal construct for each of the group's school subjects. If the group contains n_i students then the mean attitude rating is given by:

$$X_{SAt} = \frac{1}{n_i} \sum_{i=1}^{n_i} x_{iSAt}$$

Where:
X is the group mean rating score
n_i is the number of students assigned to the group
and all other subscripts have their usual meanings

The instrument also calculates two measures of mean response to each of the measured attitudinal constructs. First, a standard arithmetic mean score for all of their subject ratings for each attitudinal construct is determined. This approach assumes that each subject course is of equal value in forming a student's composite attitude for each construct. Second, a weighted mean is calculated based on the relative number of lessons allocated to that subject in a student's timetable cycle. The rationale for this weighted mean is that a student's composite attitudes may be more influenced by their attitudes towards subjects that they spend more time studying. These mean measures allow for a general or balanced measure of a student's attitudes towards their academic school life as a whole to be estimated. In maintaining consistency with the theory of reasoned action (Fishbein & Ajzen, 2011), we have used this second measure of mean attitude throughout the analyses of this study with the understanding that greater exposure to a course of study will develop stronger attitudes towards it and hence cause it to exert greater weight in the formation of composite attitudes. This composite attitude rating is determined for each student per attitudinal construct, at a given time based on the number of lessons *(N)* allocated to each subject per timetable cycle. It is calculated as follows:

$$\bar{x}_{iAt} = \frac{\sum_{S=1}^{n_S} N_S \cdot x_{iSAt}}{\sum_{S=1}^{n_S} N_S}$$

Where:
$\bar{x}$ is the composite attitude rating
N_S is the number of lessons assigned to subject S per timetable cycle
and all other sybols and subscripts have their previous meanings

The composite attitude ratings for each attitudinal construct for a given group of students—for example, female students or metropolitan students—at a defined time can then be visualised in the form of a Composite Attitude Profile [CAP]. Figure 6.3 shows four CAPs arranged so as to allow for easy visual comparison between two groupings. A CAP is best visualised in the form of a boxplot. The group's mean composite rating for each attitudinal construct is calculated as follows:

$$\bar{X}_{At} = \frac{1}{n_i} \sum_{i=1}^{n_i} \bar{x}_{iAt}$$

Where:
$\bar{X}$ is the group mean composite attitude rating
n_i is the number of students assigned to the group
and all other symbols and subscripts have their previous meanings

This measure of composite attitudes for an individual student allows for their reported attitudes towards a particular subject to be *normalised* to an average of zero at the measured point in time. To do this, the student's composite attitude rating for each attitudinal construct is subtracted from their subject specific raw attitude rating for the same construct. This yields a rating that represents a student's attitude rating for a given subject *relative* to their composite attitude rating for that same attitudinal construct at the same point in time. This subject attitude rating is calculated as follows:

$$\langle x \rangle_{iSAt} = x_{iSAt} - \bar{x}_{iAt}$$

Where:
$\langle x \rangle$ is the subject attitude rating for an individual student

The subject attitude ratings can then be visualised in the form of a matrix of bar charts which we refer to as a Subject Attitude Profile [SAP]. That is to say, for a particular student their SAPs record their personal attitudes, at specific points in time, towards all seven attitudinal constructs, for each of their school subjects while correcting for the fact that different students have different baseline attitudes towards school in general. More usefully, the SAP for a school subject can be calculated for a given group of students which indicates the group's mean attitude rating for each attitudinal factor at a given time for a specific subject while correcting for the individual baselines towards school in general. The group mean subject attitude rating can be calculated as follows:

$$\langle X \rangle_{SAt} = \frac{1}{n_i} \sum_{i=1}^{n_i} (x_{iSAt} - \bar{x}_{iAt})$$

Where:
$\langle X \rangle$ is the group mean subject attitude rating for an individual student

An example of a full AP for a student from a metropolitan selective boys school in term 1 of Year 7 is given as Figure 6.2.

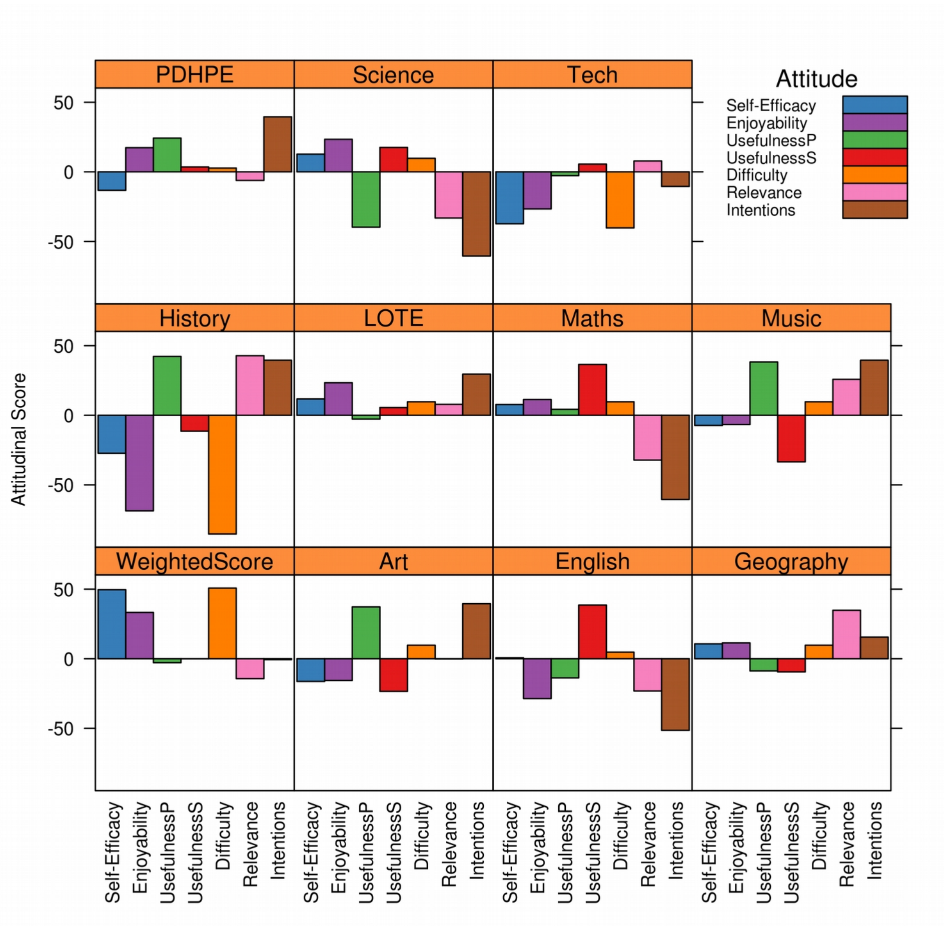

Figure 6.2: An example of a cross-sectional attitudinal profile for a single Year 7 student.

This student's profile was captured in Term 1 of year 7 for a student who attends a selective boys' school in the Sydney metropolitan area.

Patterns of interest, both within and between STEM subject areas, were identified and then investigated further through the use of notched boxplot comparisons (Sarkar, 2008), linear modelling, ANOVA, and correlation analysis using various packages available in the R statistical analysis environment (R Core Team, 2014). Quantile-quantile plots and the Shapiro-Wilk W-statistic were utilised to ensure adequate normality in the data for the use of parametric statistics. Tukey's Honest Significance Test, with a 95% confidence interval, was used to determine the extent of the differences in the population means identified in the ANOVA results and eta-squared (η^2) was used as a measure of effect size. Pearson's product moment coefficient was used to analyse the strength of correlations between attitudinal factors within a subject's AP. Following Cohen's rule of thumb for effect sizes (1988)—and relevant conversions of Cohen's d to r and η^2—the relative strength of given effect sizes will be interpreted using the cutoff values in Table 6.1 and indicated in the discussion using the † symbol. These analyses are presented in the results section.

Table 6.1: Magnitudes of effect size based on the general rules of thumb of Cohen (1988).

The dagger symbol † is used in the following statistical analyses to indicate the relative size of the effect shown.

Statistical Measure	**Effect Size Threshold**		
	Small†	**Moderate††**	**Strong†††**
Cohen's d	0.20	0.50	0.80
Correlation (Pearson's r)	0.10	0.30	0.50
ANOVA (η^2)	0.01	0.06	0.14

For the sake of clarity in analysis—and due to a number of uncontrollable administrative issues such as varying initial measurement dates, missing data points and longitudinal attrition—the analysed data for students in Year 7 in 2015 or 2016, have been plotted as two time-based record groups; Semester 1 (comprising measurements made in Terms 1 and 2) and Semester 2 (comprising Terms 3 and 4). As some students provided data in both terms of a semester, the total number of included data points can exceed the number of students contributing data. In Semester 1 there were 451 observations (397 female, 54 male) and in Semester 2 there were 252 observations (189 female, 63 male). The unbalanced nature of the sample combined with the uneven attrition rates between semesters needs to be kept in mind in interpreting and generalising from these results.

Results

Composite Attitudinal Profiles (CAP)

Figure 6.3 compares the CAP for all male and female students towards school in general at two points in Year 7, while Table 6.2 lists the means, standard deviations and number of subjects for each aspect of this AP. The additional space available when analysing the individual components of a full AP allows for the use of a notched boxplot approach to analysis. In the CAP, and all subsequent SAPs, the filled circle represents the mean rating score for an attitudinal construct, while the box represents the inter-quartile range [IQR] on the results. The dotted whisker lines extend a further 1.5 times the IQR beyond the box thereby capturing 99% of all the observations assuming a normal distribution. The empty circles identify possible outliers in the data. The notches represent the confidence interval around the mean and act as an indicator that the means of two attitudes ratings are significantly different if their notches do not overlap. Shading has been used for each of the attitudinal factors to facilitate the straightforward formation of comparisons.

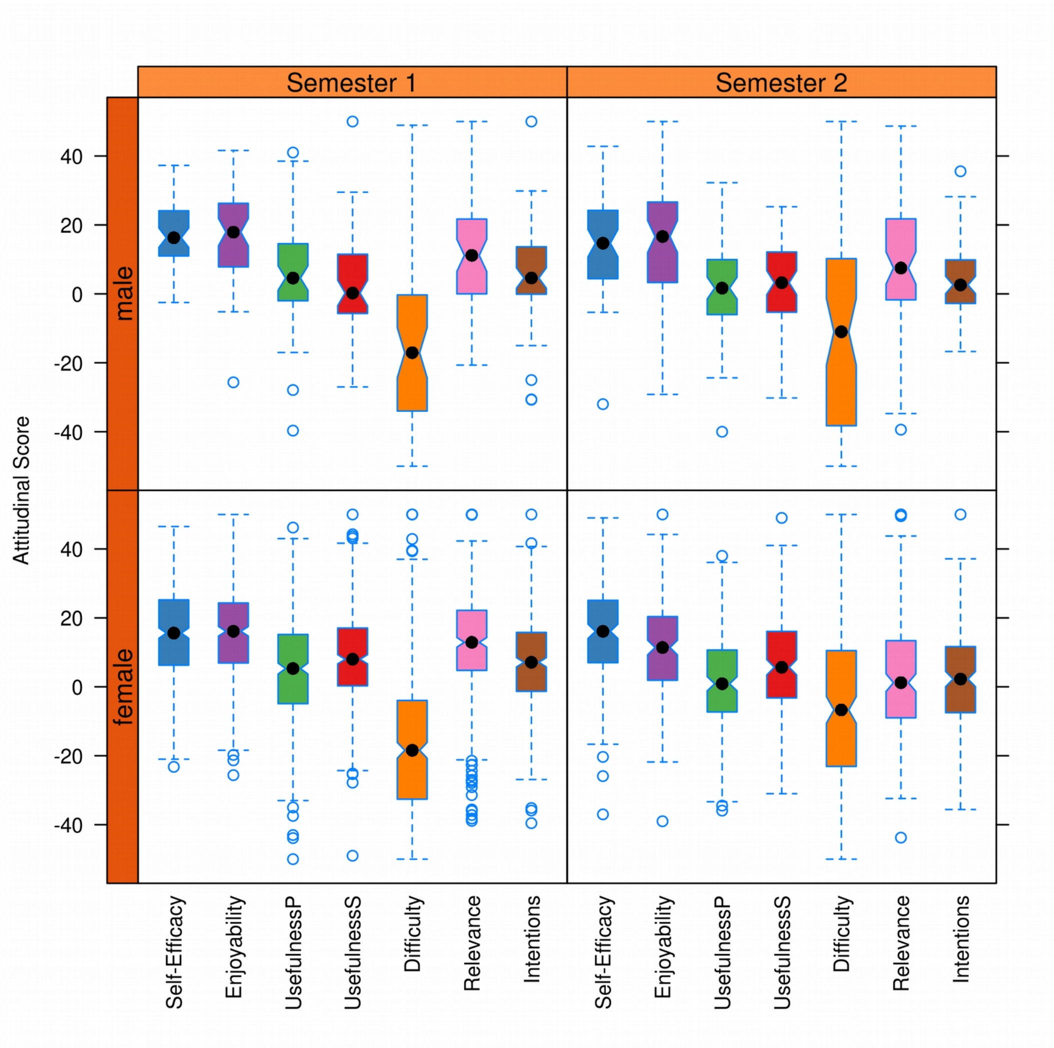

Figure 6.3: General Academic Attitudinal Profile of Year 7 students during semesters 1 and 2.

The upper panel allows for comparison of male students while the lower indicates female student attitudes. The notch indicates the 95% confidence interval of the median, while the box indicates the inter-quartile range.

The standard deviations presented in Table 6.2 describe an alternative representation of the spread of attitudes within a particular cohort or participant group and show information similar to the lengths of the notched boxes shown in the attitude profiles (Figure 6.3). While the standard deviations in Table 6.2 appear large compared to the mean ratings, they do not impact on the reliability of the time-series trends discussed below. These analyses focus on changes to the group means over time and therefore it is the change in standard deviation which would affect reliability and not the overall measure of SD. In this context, the SDs are not of significant size.

As can be seen in both of these representations, students start Year 7 with reasonably positive attitudes towards school and there is very little difference between the mean ratings of male and female students. The large negative values for difficulty indicate that most students tended to perceive school to be relatively easy although there is a large spread in these ratings. The large positive va lues for self-efficacy, enjoyability and relevance suggest that on average students feel positive about their early experiences of their high-school subjects.

Table 6.2: Means and standard deviations for the Attitudinal Constructs comprising the Composite Attitude Profile.

*Means that are statistically significantly different between semesters 1 and 2 are indicated with an * on the top line of each row while those that show statistically significant differences between the sexes are indicated on the subsequent lines (* p<.05, ** p<.01, *** p<.001). Similarly, the effect sizes (η^2) differences in the means corresponding to these statistically significant changes are indicated with the † symbol († η^2 >0.01 small, †† η^2 >0.06 medium ,††† η^2 >0.14 strong).*

Attitude	Semester 1		Semester 2	
	Mean	S.D	Mean	S.D
Self-Efficacy	15.86	12.10	15.35	13.80
female	*15.66*	*12.34*	*15.60*	*13.89*
male	*17.37*	*10.14*	*14.62*	*13.62*
Enjoyability	15.82** †	12.94	12.51** †	15.46
female	*15.59**	*12.99*	*11.61**	*14.99*
male	*17.58**	*12.54*	*15.21**	*16.64*
Personal Usefulness	4.63** †	15.31	1.57** †	14.07
female	*4.51*	*15.42*	*1.41*	14.38
male	*5.51*	*14.56*	*2.02*	13.17
Specific Usefulness	8.14** ††	13.40	5.57 ** ††	14.15
female	*8.77*** †*	*13.21*	*6.56*** †*	14.35
male	*3.57*** †*	*14.05*	*2.60*** †*	13.20
Difficulty	-17.36*** †	20.84	-7.90*** †	25.21
female	*-17.67*	*20.31*	*-7.02*	*23.14*
male	*-15.12*	*24.46*	*-10.54*	*30.67*
Relevance	12.26*** ††	15.37	3.56*** ††	17.28
female	*12.50**	*15.47*	*2.18**	*16.75*
male	*10.48**	*14.60*	*7.72**	*18.29*
Intentions	6.86*** †	14.25	2.14*** †	13.94
female	*7.16*	*14.18*	*1.42*	*14.81*
male	*4.66*	*14.74*	*4.31*	*10.74*

When considering students' reported self-efficacy towards their school subjects as a whole (Figure 6.3) there are no significant differences between semester 1 and semester 2. Similarly any differences between male and female students are not statistically significant. However, analysis of variance indicates that for all other attitudes, there are some levels of statistically significant difference. In the following discussions the † symbol is used to indicate the relative effect size in accordance with Table 6.1.

Student attitudes toward school subjects in general

Enjoyability: Students' perceptions of the enjoyability of their school subjects reveal statistically significant differences over time and between the sexes. Students' ratings of enjoyability for school subjects in general fell by 3.31 points ($F(1,699)=9.20$, $p=.003$, $\eta^2=.013^{\dagger}$) between semesters 1 and 2 while female students rated enjoyability 2.72 points ($F(1,699)=3.85$, $p=.05$, $\eta^2=.005$) higher than their male peers on average.

Personal usefulness: This attitude exhibited statistically significant changes over time for students' school subjects as a whole (Table 6.2). Students' perceptions of the usefulness of school subjects to their personal lives fell by 3.06 points ($F(1,699)=9.85$, $p=.009$, $\eta^2=.014^{\dagger}$) between Semesters 1 and 2. These changes over time appear not to be associated with student sex and show an eta-squared effect size that is very small.

Usefulness for specific future careers: Student ratings of this construct show statistically significant differences over time and between the sexes. Students' ratings for the usefulness of their school subjects for typical careers in those fields fell by 2.57 points ($F(1,698)=5.78$, $p=.017$, $\eta^2=.008$) between semesters 1 and 2. Female students typically rated this usefulness 4.45 points ($F(1,698)=10.77$, $p=.001$, $\eta^2=.015^{\dagger}$) lower than male students.

Difficulty: Difficulty exhibited statistically significant changes over time for students' school subjects as a whole (Table 6.2). Mean difficulty rose by 9.46 points ($F(1,698)=28.52$, $p<.001$, $\eta^2=.039^{\dagger}$) between semesters 1 and 2. These changes over time appear not to be associated with student sex and show an eta-squared effect size that is small.

Relevance: Results showed sex specific trends around students' perceptions of the everyday relevance of what they learnt at school. The students reported a fall in relevance of 8.70 ($F(1,697)=47.50$, $p<.001$, $\eta^2=.063^{\dagger\dagger}$) points between semester 1 and semester 2 with female students reporting a fall of 10.32 points compared to a fall of 2.76 points for males. This difference was statistically significant ($F(1,697)=5.28$, $p=.022$, $\eta^2=.007$).

Intentions: Students intentions to continue with their Year 7 subject combinations beyond Year 10 fell on average by 4.71 points ($F(1,697)=17.96$, $p<.001$, $\eta^2=.018^{\dagger}$) between semester 1 and semester 2 and although there appears to be a difference between the sexes (Table 6.2) this was not statistically significant.

Student attitudes towards science

Following the same process as above yields the SAP for science shown in Figure 6.4 and the table of means (Table 6.3). A visual comparison of the science SAP with the CAP (Figure 6.3) shows that students tend to have more neutral attitudes towards science than towards their other school subjects combined. There also appears to be less variance in these attitudes across the sample students. Male students in particular seem to acknowledge the usefulness of school science for scientific careers, with the mean 15.26 points above their average rating for their school subjects during Semester 1 of Year 7. At this same point in time, both male and female students indicated that they intended to continue to study some form of science into Years 11 and 12 with the means 10.84 and 6.38 points above their average rating.

The SAPs for science (Figure 6.4) show no statistically significant changes in attitudes between semesters 1 and 2 for either male or female students, in terms of personal usefulness, difficulty, relevance or intentions in relation to science when compared against their other school subjects. The differences found for the other attitudinal constructs in relation to science are as follows:

Self-efficacy: Female students reported levels of self-efficacy 4.02 points lower on average than male students which was statistically significant ($F(1,697)=8.03$, $p=.004$, $\eta^2=.011^{\dagger}$). However this did not change significantly over time.

Enjoyability: Similarly, female students reported a statistically significantly different ($F(1,697)=15.88$, $p<.001$, $\eta^2=.022^{\dagger}$) rating for enjoyability compared to their male counterparts averaging 8.97 points lower. Students of both sexes reported greater enjoyability in semester 2 than in semester 1, with a mean rise of 4.05 points, and this was again statistically significant ($F(1,697)=5.21$, $p=.023$, $\eta^2=.007$).

Usefulness for specific careers: Interestingly, while male students reported very positive attitudes towards science as being useful for scientific careers, the students overall reported an increase in usefulness of science compared to their other subjects of 3.86 points between semesters 1 and 2 and this was statistically significant ($F(1,697)=3.89$, $p=0.049$, $\eta^2=.006$).

For the science attitudes there are strong (see Table 6.1) correlations (Table 6.4) between the enjoyability of the subject and a student's intentions to continue with its study into Year 11 and 12 ($r(696)=0.60^{\dagger\dagger\dagger}$), and also between subject relevance and intentions (r(696)=0.53†††)). Moderate correlations also exist between the perceived usefulness of school science for scientific careers and each of self-efficacy, enjoyability, relevance and intentions.

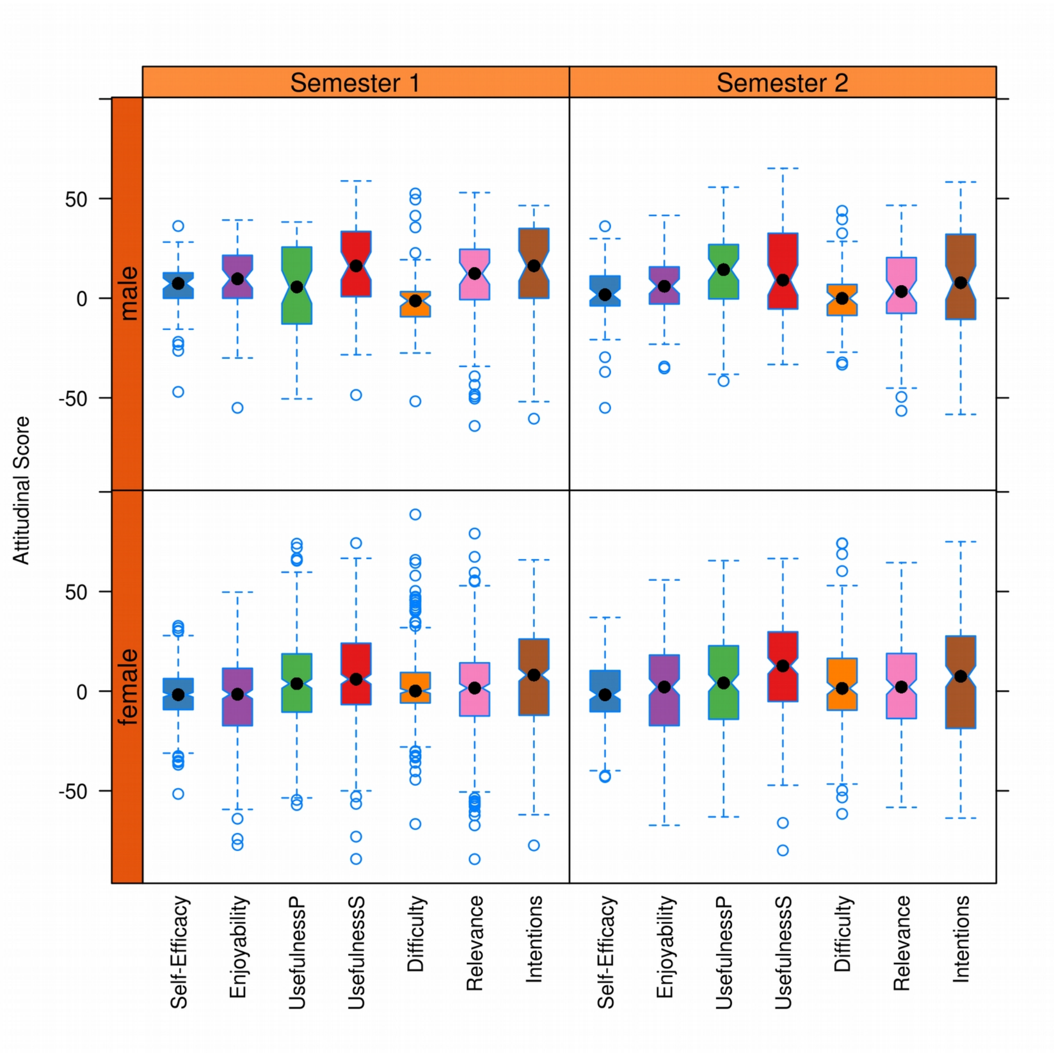

Figure 6.4: Attitudinal Profile of Year 7 students during semesters 1 and 2 toward science.

The upper panels indicate the SAP for male students while the lower panels indicates female students.

Table 6.3: Means and standard deviations for the Attitudinal Constructs comprising the Subject Attitude Profile for science.

*Note that values presented are calculated relative to each student's personal composite attitude rating for that construct. Means that are statistically significantly different between semesters 1 and 2 are indicated with an * on the top line of each row while those that show statistically significant differences between the sexes are indicated on the subsequent lines (* p<.05, ** p<.01, *** p<.001). Similarly, the effect sizes (η^2) differences in the means corresponding to these statistically significant changes are indicated with the † symbol († η^2 >0.01 small, †† η^2 >0.06 medium ,††† η^2 >0.14 strong).*

Attitude	Semester 1		Semester 2	
	Mean	**S.D**	**Mean**	**S.D**
Self-Efficacy	-0.75	13.36	-0.38	15.87
female	*-1.52*** †*	*13.08*	*-0.87*** †*	*16.03*
male	*4.91*** †*	14.17	*1.00*** †*	*15.37*
Enjoyability	-2.21*	22.57	1.84*	23.20
female	*-3.67**** †*	*22.72*	*0.26**** †*	*24.70*
male	*8.47**** †*	*18.38*	*6.56**** †*	*17.25*
Personal Usefulness	3.66	23.74	5.15	26.42
female	*3.78*	*23.54*	*3.41*	*27.19*
male	*2.73*	25.33	*10.37*	23.37
Specific Usefulness	8.27*	24.53	12.14*	25.59
female	*7.32*	*24.66*	*12.10*	*26.03*
male	*15.26*	22.59	*12.24*	*24.40*
Difficulty	1.99	17.35	2.85	22.24
female	*2.42*	*17.22*	*3.61*	*24.15*
male	*-1.21*	*18.15*	*0.56*	*15.06*
Relevance	0.86	23.32	2.99	23.92
female	*0.20*	*22.79*	*2.77*	*24.21*
male	*5.71*	*26.60*	*3.69*	*23.18*
Intentions	6.92	26.53	4.45	30.50
female	*6.38*	*26.48*	*3.34*	29.93
male	*10.84*	*26.73*	*7.76*	32.16

Table 6.4: Correlation matrix for attitudinal constructs within the science Subject Attitude Profile.

The relative effect sizes (r) corresponding to these correlations are indicated with the † symbol († |r| >0.1 small, †† |r| >0.3 medium ,††† |r |>0.5 strong).

	Self-Efficacy	Enjoyability	Personal Usefulness	Specific Usefulness	Difficulty	Relevance
Enjoyability	0.60†††					
Personal Usefulness	0.31††	0.33††				
Specific Usefulness	*0.47*††	*0.47*††	0.34††			
Difficulty	-0.29†	-0.23†	-0.18†	-0.17†		
Relevance	0.27†	0.30††	*0.38*††	*0.38*††	-0.24†	
Intentions	0.30††	0.29†	*0.38*††	*0.39*††	-0.22†	0.53†††

Student attitudes towards mathematics

Student attitudes towards mathematics are depicted in Table 6.5 and Figure 6.5. Comparing Figure 6.5 with Figure 6.3 reveals that during the first semester of Year 7 students have a more negative SAP in relation to mathematics than towards their other school subjects. In particular female students rate mathematics 10.33 points lower than the rest of their school subjects in terms of personal usefulness while male students rate mathematics 6.21 points lower in terms of enjoyability. However, even though they report negative attitudes, male and female students both indicate strong intentions to continue mathematics into Years 11 and 12 compared to their other subjects (10.81 points higher than average). In addition both male and female students recognise the usefulness of school mathematics for careers in that field, rating the subject 16.37 points higher than in their CAP.

Analysing the changes in reported attitudes towards mathematics shows no statistically significant differences for the constructs of enjoyability or difficulty between male and female students, and neither of these attitude ratings change between semester 1 and semester 2 in any significant way. Of the other attitudinal constructs measured, the statistically significant differences were as follows:

Self-efficacy: This construct shows a statistically significant ($F(1,697)=9.88$, $p=.002$, $\eta^2=.014$†) dependence on student sex with female students reporting scores 5.32 points lower than their male peers throughout the year.

Personal Usefulness: Students perceptions of the personal usefulness of mathematics significantly increased by 6.66 points on average between semester 1 and semester 2 ($F(1,697)=12.44$, $p<.001$, $\eta^2=.018^{\dagger}$). This construct also demonstrated significant ($F(1,697)=5.29$, $p=.022$, $\eta^2=.008$) differences between males and females with female students reporting rises of 8.24 points while male students reported a decline of 3.10 points.

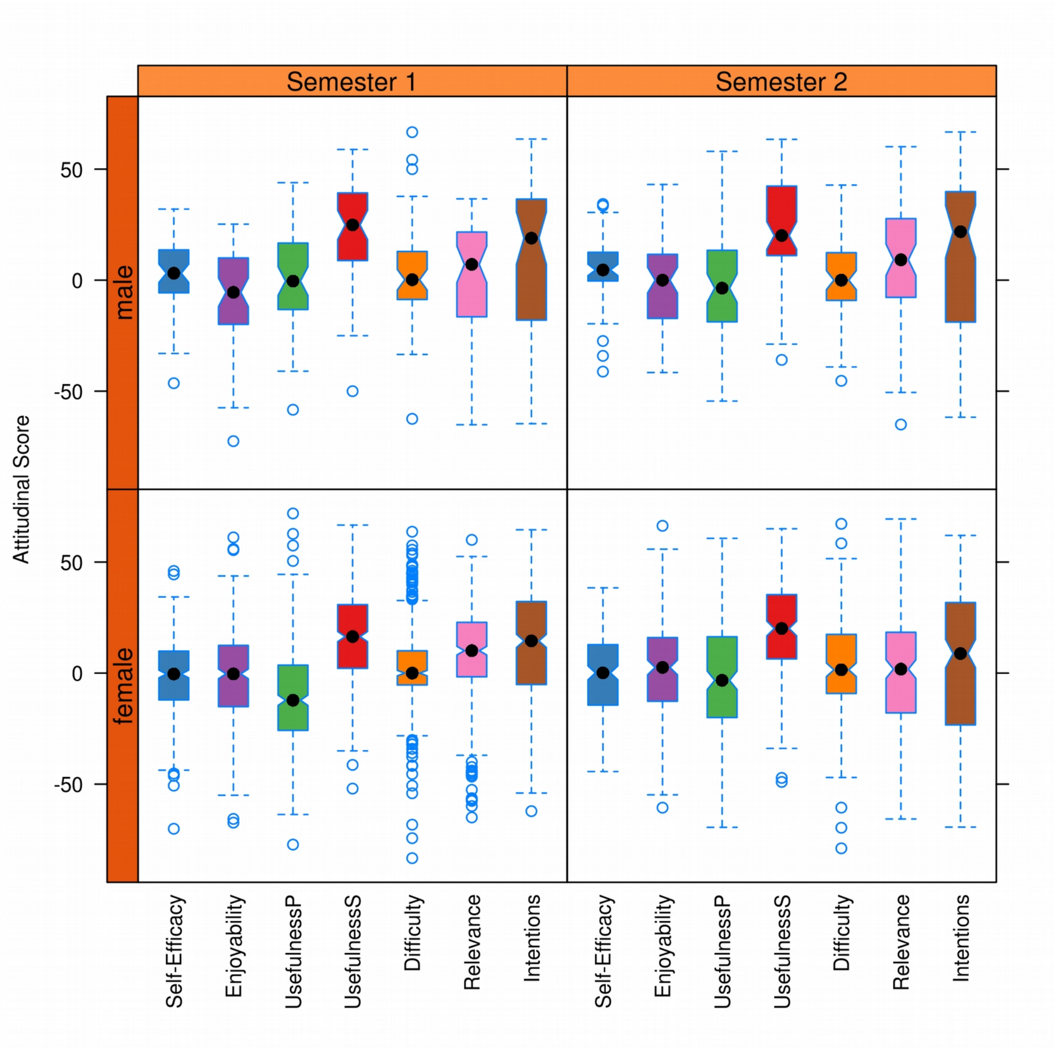

Figure 6.5: Subject Attitudinal Profile of Year 7 students during semesters 1 and 2 toward mathematics.

The upper panels indicate the SAP for male students while the lower panels indicates female students.

Table 6.5: Means and standard deviations for the Attitudinal Constructs comprising the Subject Attitude Profile for mathematics.

*Note that values presented are calculated relative to each student's personal composite attitude rating for that construct. Means that are statistically significantly different between semesters 1 and 2 are indicated with an * on the top line of each row while those that show statistically significant differences between the sexes are indicated on the subsequent lines (* p<.05, ** p<.01, *** p<.001). Similarly, the effect sizes (η^2) differences in the means corresponding to these statistically significant changes are indicated with the † symbol († η^2 >0.01 small, †† η^2 >0.06 medium ,††† η^2 >0.14 strong).*

Attitude	Semester 1		Semester 2	
	Mean	S.D	Mean	S.D
Self-Efficacy	-1.16	16.87	0.45	17.43
female	*-1.71*** †*	*16.88*	*-1.16*** †*	*19.98*
male	*2.83*** †*	*16.38*	*5.25*** †*	*14.76*
Enjoyability	-2.25	20.39	0.20	21.74
female	*-1.71*	*20.25*	*0.98*	*22.33*
male	*-6.21*	*21.12*	-2.13	*19.84*
Personal Usefulness	-9.16*** †	22.93	-2.50 *** †	26.05
female	*-10.33**	*22.72*	*-2.09**	*26.96*
male	*-0.64**	*22.86*	*-3.74**	*23.26*
Specific Usefulness	16.37*	20.24	20.51*	22.10
female	*15.86*	*19.73*	*19.85*	*21.32*
male	*20.11*	*23.52*	*22.46*	*24.38*
Difficulty	2.60	19.62	1.98	22.45
female	*2.54*	*19.18*	*2.47*	*23.71*
male	*3.05*	*22.80*	*0.51*	*18.19*
Relevance	7.31*	22.17	2.63*	26.92
female	*8.31*** †*	*21.16*	*0.89*** †*	*27.00*
male	*-0.03*** †*	*27.65*	*7.83*** †*	*26.21*
Intentions	10.81*	27.42	5.81*	33.68
female	*10.95*	*26.56*	*4.37*	*32.86*
male	*9.74*	*33.32*	*10.11*	*35.95*

Usefulness for specific careers: This construct shows statistically significant changes between semester 1 and semester 2 with no significant differences between the ratings of male and female students. Students' perceptions of the specific usefulness of mathematics increased by 4.13 points on average ($F(1,697)=6.30$, $p=.012$, $\eta^2=.009$).

Relevance: The students' perceptions of the relevance of school mathematics declined significantly ($F(1,697)=6.23$, $p=.013$, $\eta^2=.009$) and with a significant dependence on student sex ($F(1,697)=9.74$, $p=.002$, $\eta^2=.014^{\dagger}$) between semesters 1 and 2—a finding that is the converse of the findings for personal usefulness. On average female students reported mathematics as 7.43 points less relevant by the end of semester 2, while male students reported an increase in relevance of 7.87 points.

Intentions: Students' intentions to continue with the study of mathematics in Years 11 and 12 show statistically significant changes between semester 1 and semester 2 with no significant differences between the ratings of male and female students. Students' intentions to study the subject fell by 5.00 points ($F(1,697)=4.54$, $p=.034$, $\eta^2=.006$) compared to their composite school rating for this construct.

Table 6.6: Correlation matrix for attitudinal constructs within the mathematics Subject Attitude Profile.

The relative effect sizes (r) corresponding to these correlations are indicated with the † symbol († $|r|>0.1$ small, †† $|r|>0.3$ medium ,††† $|r|>0.5$ strong).

	Self-Efficacy	Enjoyability	Personal Usefulness	Specific Usefulness	Difficulty	Relevance
Enjoyability	$0.41^{\dagger\dagger}$					
Personal Usefulness	$0.33^{\dagger\dagger}$	$0.26^{\dagger}$				
Specific Usefulness	$0.32^{\dagger\dagger}$	$0.27^{\dagger}$	$0.26^{\dagger}$			
Difficulty	$-0.25^{\dagger}$	$-0.20^{\dagger}$	$-0.24^{\dagger}$	$-0.11^{\dagger}$		
Relevance	$0.15^{\dagger}$	$0.12^{\dagger}$	0.07	$0.20^{\dagger}$	$-0.15^{\dagger}$	
Intentions	$0.20^{\dagger}$	$0.18^{\dagger}$	0.08	$0.19^{\dagger}$	$-0.16^{\dagger}$	$0.50^{\dagger\dagger\dagger}$

There are generally weak correlations (Table 6.6) between the mathematics attitudes offering little insight into the interactions between the attitudinal factors. However, there is a moderate correlation ($r(695)=0.41^{\dagger\dagger}$) between self-efficacy and enjoyability and a borderline strong correlation ($r(695)=0.50^{\dagger\dagger\dagger}$) between relevance to the world and students' intentions to continue with further study.

Student attitudes towards technologies

The SAP for technologies (Figure 6.6) and the corresponding table of means (Table 6.7) show rather different profiles for male and female students during semester 1 of Year 7. It is worth noting that technologies in Year 7 encompasses a number of discrete knowledge areas—e.g. textiles, timber, food technology and computer programming—between which the data collection instrument does not necessarily differentiate. This range of knowledge areas therefore will be an underlying influence on the technologies SAPs. Male students show a relatively neutral SAP for technologies compared to their CAP, while female students indicate an SAP that is more positive than their CAP, especially in the areas of intentions to continue to further study (9.46 points above average), Enjoyability (15.43 points above average) and personal usefulness of the subject (20.24 points above average).

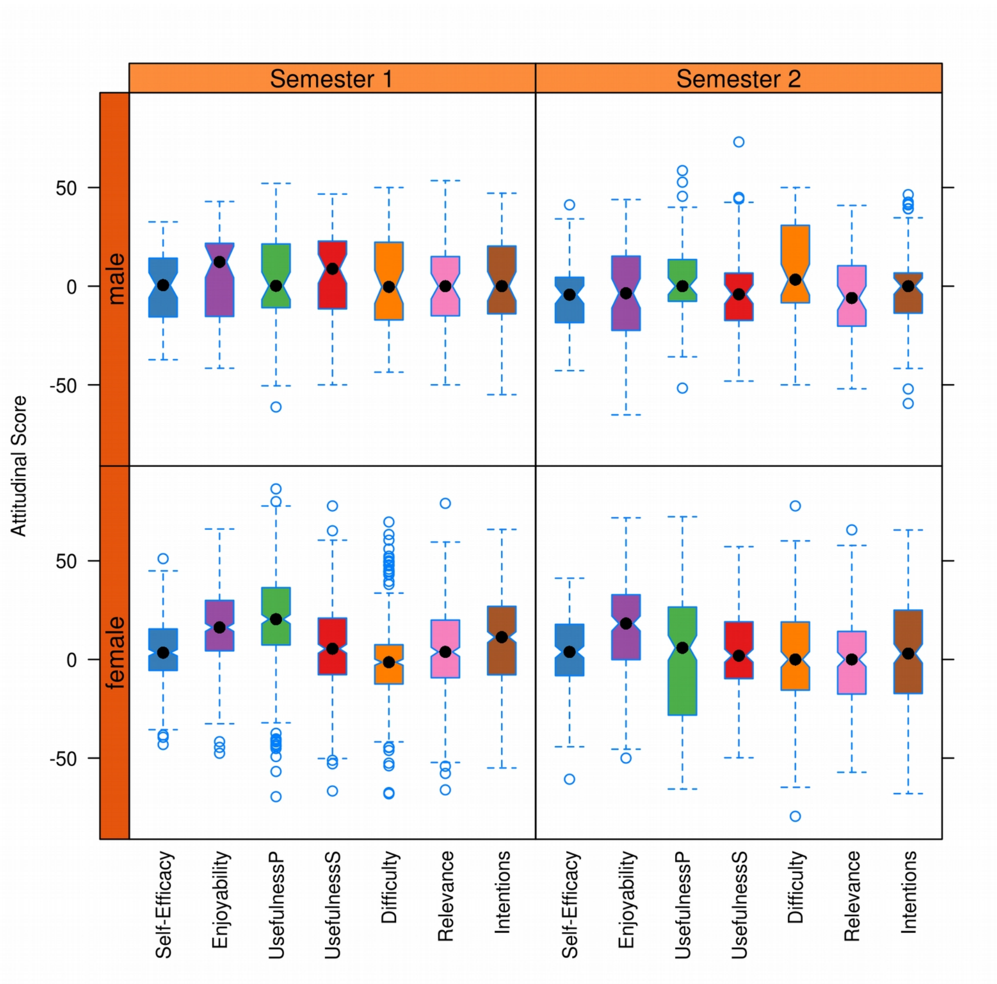

Figure 6.6: Subject Attitudinal Profile of Year 7 students during semesters 1 and 2 toward technologies.

The upper panels indicate the SAP for male students while the lower panels indicates female students.

All attitudes show some statistically significant trends as outlined below.

Self-efficacy: Female students reported self-efficacy as 6.50 points higher than their male peers ($F(1,697)=14.20$, $p<.001$, $\eta^2=.020^{\dagger}$) and this showed no significant changes over time.

Enjoyability: Females ratings of enjoyability of technologies were 14.55 points higher than male students' ratings ($F(1,697)=45.66, p<.001$, $\eta^2=.061^{\dagger\dagger}$), however this also showed a significant change between semesters 1 and 2 ($F(1,697)=4.15, p=0.042$, $\eta^2=.006$). Female students showed an increase of just 0.59 rating points between semesters while male students reported a fall of 8.44 points in their ratings over the same time period.

Personal usefulness: Significant differences were apparent between semesters 1 and 2 ($F(1,697)=60.32, p<.001$, $\eta^2=.080^{\dagger\dagger}$) and between female and male students ($F(1,697)=10.06$, $p=.002$, $\eta^2=.014^{\dagger}$) as well as a significant interaction term between these two contrasts($F(1,697)=13.22$, $p<.001$, $\eta^2=.019^{\dagger}$). Personal usefulness fell by 16.29 points between the semesters and male students on average reported scores 8.44 points lower than female students. However, considering the interaction term, female students showed a drop in personal usefulness of 18.86 points between the two semesters compared with their other school subjects, while male students reported an increase of 1.05 points relative to their other school subjects.

Usefulness for specific careers: Male and female students both reported a statistically significant difference in ratings for this construct between semester 1 and semester 2. The ratings for usefulness declined by 4.47 points on average ($F(1,697)=6.45$, $p=.011$, $\eta^2=.009$) during this period.

Difficulty: Male students' ratings indicated that technologies was a significantly ($F(1,697)=4.28, p=.039$, $\eta^2=.006$) more difficult area of their curriculum in comparison to female ratings—a difference of 4.80 points.

Relevance: Both male and female students reported that the relevance of technologies changed significantly between semester 1 and semester 2, falling by 4.99 points ($F(1,697)=7.73$, $p=.006$, $\eta^2=.011^{\dagger}$).

Table 6.7: Means and standard deviations for the Attitudinal Constructs comprising the Subject Attitude Profile for technologies.

*Note that values presented are calculated relative to each student's personal composite attitude rating for that construct. Means that are statistically significantly different between semesters 1 and 2 are indicated with an * on the top line of each row while those that show statistically significant differences between the sexes are indicated on the subsequent lines (* p<.05, ** p<.01, *** p<.001). Similarly, the effect sizes (η^2) differences in the means corresponding to these statistically significant changes are indicated with the † symbol († η^2 >0.01 small, †† η^2 >0.06 medium ,††† η^2 >0.14 strong).*

Attitude	Semester 1		Semester 2	
	Mean	**S.D**	**Mean**	**S.D**
Self-Efficacy	3.27	16.53	0.68	18.91
female	*3.88*** †*	*16.29*	*2.76*** †*	*18.86*
male	*-1.18*** †*	*17.72*	*-5.55*** †*	*17.78*
Enjoyability	14.17*	20.31	11.14*	25.46
female	*15.43*** ††*	*19.62*	*16.01*** ††*	*23.79*
male	*4.95*** ††*	*22.95*	*-3.48*** ††*	*24.86*
Personal Usefulness	18.00*** ††	25.25	1.70*** ††	30.00
female	*20.24** †*	*24.11*	*1.38*** †*	*32.49*
male	*1.62** †*	*27.51*	*2.67*** †*	*21.01*
Specific Usefulness	5.81*	22.75	1.34*	21.73
female	*5.68*	*22.82*	*2.68*	*21.53*
male	*6.74*	*22.43*	-2.71	*21.98*
Difficulty	-0.89	20.78	2.20	27.23
female	*-1.24**	*20.06*	*0.46**	*27.11*
male	*1.66**	*25.46*	*7.45**	*27.10*
Relevance	3.64** †	21.77	-1.35** †	24.49
female	*4.00*	*21.77*	-0.76	*25.17*
male	*1.01*	*21.76*	-3.12	*22.40*
Intentions	8.54*** †	24.90	1.17*** †	26.04
female	*9.46**	*24.59*	*2.16**	*27.25*
male	1.76*	*25.57*	-1.79*	*21.94*

Table 6.8: Correlation matrix for attitudinal constructs within the technologies Subject Attitude Profile.

The relative effect sizes (r) corresponding to these correlations are indicated with the † symbol († |r| >0.1 small, †† |r| >0.3 medium ,††† |r |>0.5 strong).

	Self-Efficacy	Enjoyability	Personal Usefulness	Specific Usefulness	Difficulty	Relevance
Enjoyability	0.68†††					
Personal Usefulness	0.28†	0.35††				
Specific Usefulness	0.48††	0.42††	0.23†			
Difficulty	-0.33††	-0.32††	-0.28†	-0.21†		
Relevance	0.38††	0.39††	0.35††	0.37††	-0.36††	
Intentions	0.35††	0.40††	0.44††	0.40††	-0.30††	0.42††

Intentions: Students' intentions to continue with study in this subject area beyond compulsory education—in this case from Year 9 onward—showed significant dependence on student sex ($F(1,697)=5.05$, $p=.025$, $\eta^2=.007$) as well as changing over the course of the year ($F(1,167)=13.73$, $p<.001$, $\eta^2=.019$†). Between semesters, intention ratings dropped by 7.36 points on average compared to other subjects with male students reporting 5.67 points lower than females on average.

There are many moderate correlations between the different attitudes towards technologies (Table 6.8), however, the only strong correlation is between self-efficacy and enjoyability ($r(695)=0.60$†††)). The correlation between usefulness for design related careers and self-efficacy is borderline strong ($r(695)=0.48$††) and may warrant further investigation.

Significant relationships between subjects

A correlation analysis between the separate attitudinal constructs of the CAP, reveals that there are a number of strong correlations (Table 6.9). Self-efficacy and enjoyability are very strongly correlated overall ($r(697)=0.67$†††)) as are subject relevance and intentions to continue study into post-compulsory education ($r(697)=0.67$†††)). Relevance and intentions also both strongly correlate with the personal usefulness of what is being studied at school ($r(697)=0.53$††† and $r(697)=0.51$††† respectively) and with the difficulty of the courses overall ($r(697)=-0.57$††† and $r(697)=-0.50$††† respectively).

Table 6.9: Correlation matrix for attitudinal constructs within the Composite Attitude Profile.

The relative effect sizes (r) corresponding to these correlations are indicated with the † symbol († |r| >0.1 small, †† |r| >0.3 medium ,††† |r |>0.5 strong).

	Self-Efficacy	Enjoyability	Personal Usefulness	Specific Usefulness	Difficulty	Relevance
Enjoyability	0.67†††					
Personal Usefulness	0.27†	0.34††				
Specific Usefulness	0.40††	0.45††	0.27†			
Difficulty	-0.21†	-0.27†	-0.40††	-0.14†		
Relevance	0.13†	0.22†	0.53†††	0.20†	-0.57†††	
Intentions	0.11†	0.20†	0.51†††	0.18†	-0.50†††	0.67†††

A similar correlation analysis between the different constructs of each of the three distinct STEM SAPs and the CAP shows that there are no statistically significant strong relationships to be found in this sample. However, there are a number of moderate correlations to be noted. Students reported a negative borderline moderate correlation (r(695)=-0.32††)) between the personal usefulness of mathematics and technologies. Students also reported a moderate correlation (r(697)=0.45††)) between the usefulness of school science for science careers and mathematics for mathematics based careers. A borderline moderate correlation (r(697)=0.31††)) was reported between student intentions to study science and intentions to study mathematics into Years 11 and 12. Intentions to continue study in mathematics also moderately correlates with students' CAP constructs of relevance (r(697)=0.39††)), intentions to continue study (r(697)=0.44††) and difficulty of school in general (r(697)=-0.39††)). Note that the negative correlation here suggests that intentions to continue with mathematics study is linked with how easy a student finds school as a whole.

Summary of Results and Discussion

The above analyses have only examined in detail three subjects from a student's Year 7 subject mix with the students in this sample studying an average of ten subjects each. Therefore caution must be used when drawing generalisations from these patterns. It is also important to note that the unintended male:female imbalance in the sample, and the over-representation of independent schools, may skew any inferences. However, within the boundaries of these caveats, it can be seen from Figure 6.3 that students generally have fairly positive attitudes towards school subjects in general in the first half of Year 7 and that these fall slightly throughout the year. That is, students tend to begin high-school with positive composite attitudes of enjoyability, relevance and usefulness, though these attitude ratings gradually diminish over the first 12 months.

How then do students' attitudes towards STEM subjects compare to school in general? On average, students consider science to be more difficult, and less enjoyable than their other subjects at the beginning of Year 7 (Table 6.3). However, they acknowledged the usefulness of science for future careers and report intentions ratings that are nearly seven points higher for science than their CAP rating for this construct. The most negative attitudinal construct reported for science was enjoyability, although this was just 2.2 points lower than the composite rating for the rest of their school subjects.

Reported attitudes towards mathematics are significantly less positive than the composite ratings in many regards (Table 6.5). Students—particularly female students—have relatively low self-efficacy, find the lessons harder, less enjoyable and far less personally useful than the combined ratings for the rest of their subjects. Considering the construct of relevance, even given the negative aspects of enjoyability and low self-efficacy, students appear to identify mathematics as a set of important skills that are essential for future life by indicating a very strong intention—over 10 points higher than the CAP—to continue to study mathematics into Year 11 and 12.

Compared to mathematics and science, technologies show an extremely positive SAP for students in comparison to the CAP, at least in the first half of Year 7 (Table 6.7). Enjoyability was rated over 14 points above the composite average while personal usefulness was rated 18 points greater. However, by semester 2, all attitudes towards technologies had become much lower.

Conclusions and Further Work

The data presented here suggest that the range of attitudes towards STEM based subjects for the participants in this study is wide and very varied, even when considering only the views of Year 7 students who have yet to experience the wider gamut of courses on offer in subsequent years of study in most high-schools. While male and female students' CAPs are in some cases notably different, their SAPs for the three STEM subjects are still very alike in many ways. In particular, the male and female students in this study tended to experience early secondary school with almost identical composite attitude ratings of enjoyability, usefulness, relevance and difficulty (Table 6.2) yet these diverged fairly rapidly in some of the STEM subject areas resulting in the broadening of the composite ratings in general. In this respect, the findings of this study show how these students' attitudes towards the STEM subjects are not fixed but can change significantly over the course of a single year. Furthermore, these analyses also show visible differences in these students' SAPs between each of the individual STEM disciplines. Thus, it can be inferred that circumstances influencing the formation of positive attitudes towards each of science, mathematics and technology are likely quite different.

Most of the changes in attitudes described show small effect sizes with respect to student sex and the passage of time from semester one to two—that is, the passage of time or a student's sex are not strong enough explanatory factors of themselves to account for the described changes in attitude. However, three attitudinal changes in particular showed a moderate effect size in this sample. Students' declining perceptions of relevance of their subjects—as seen in the CAP—studied between semester 1 and semester 2 indicates that time is a significant explanatory factor in understanding the trends. This means that without the influence of other factors, it could be expected that as time progresses, students' perceptions of the relevance of school in general are likely to decline. As the passage of time itself cannot explain the changes it is important to consider which of the experiences Year 7 students gain over this year, and that are likely to be similar between schools across NSW, might reasonably be associated with perceived relevance. Similarly, the attitudinal construct personal usefulness towards technologies shows a moderate effect size with respect to time that might be used to begin to investigate some of the underlying causes in the changes in this attitude. The trends shown for the enjoyability of technologies demonstrate a difference between male and female students (Figure 6.6 and Table 6.7) with a moderate effect size with regards to student sex.

Based on the evidence of the correlation matrices for this sample group (Tables 6.4, 6.6 and 6.8), the attitudes that appear to have the strongest association with a student's intentions to continue study in the STEM fields are relevance and personal usefulness, while enjoyability and self-efficacy are also reasonably strongly linked. This finding is in common agreement with other research (Ardies et al., 2015; Lyons & Quinn, 2010; Sheldrake, Mujtaba, & Reiss, 2017) and suggests that these foci may offer a promising pathway to improving enrolment intentions at least for Year 7 students.

This analysis raises other questions that require further research. First, the Science and Innovation Agenda (Commonwealth of Australia, 2015) put forward by government and adopted by many educational institutions, in many ways combines the STEM disciplines under one umbrella. However, this analysis, which adopted the de-facto curriculum model of separate S, T, and M subjects common in Australian schools, shows that they appear to remain distinct discipline entities from a student perspective with distinct attitudinal characteristics. Given this apparent status, the extent to which integrated STEM initiatives alone might lead to the development of the espoused positive attitudes in school students to STEM in general would be an interesting avenue to explore.

Secondly, this study has shown that a number of aspects of students' SAPs in the STEM disciplines are declining over the first year of high-school. This is some respects contradicts the not infrequent claim in the literature that attitudes and intentions towards STEM are formed in Primary school (e.g., Jenkins & Nelson, 2005; Murphy & Beggs, 2003; Turner & Ireson, 2010). Clearly for the students in this study, early high-school experiences are still influencing their attitudes to science, mathematics and technology. Potvin and Hasni (2014a, p. 786) analysed 21 studies that reported a decline in either interest, attitude or motivation towards school science at various points along the primary-secondary school journey. However, although this previous research (e.g., Campbell, 2001; Kirikkaya, 2011; Sorge, 2007; Speering & Rennie, 1996; Turner & Ireson, 2010) has explored declining attitudes towards science over the primary-secondary school transition, what remains unclear is the relative magnitude of attitudinal changes and differences between primary and high-school students. Additionally, these studies have also tended to consider attitudes towards science in isolation from attitudes towards school in general. While a larger study conducted more frequently may reveal a turning point in attitudes within Year 7, it should also be considered that sub-optimal attitudes towards the STEM disciplines may already be substantially formed before students reach the high-school gates. In this respect, it would be helpful to re-validate and repeat this study within the context of upper-primary schools while also tracking students across the primary-secondary school divide. The data from such a study would likely be invaluable in informing the most appropriate timing for the plethora of opportunities—such as competitions, outreach and extension programmes—available to schools in the STEM areas.

6.4 Statement of authors' contribution

We, the PhD candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in this thesis and they have accepted the candidate's contribution as indicated in the Statement of Originality.

	Author's Name	% of contribution
Candidate	JohnPaul Kennedy	75
Other Authors	Dr Frances Quinn	15
	Associate Professor Terry Lyons	10

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25th September 2018

[redacted]
Dr Frances Quinn
(Principal Supervisor)

25th September 2018

6.5 Statement of originality

We, the PhD candidate and the candidate's Principal Supervisor, certify that the following text, figures and diagrams are the candidate's original work.

Type of Work	Page Number/s
Figure 6.1	142
Figure 6.2	145
Figure 6.3	148
Figure 6.4	155
Figure 6.5	158
Figure 6.6	161

[redacted]

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25th September 2018

Chapter 7: A longitudinal analysis of student attitudes of enjoyability and relevance towards school science across the first two years of Australian high-school.

7.1 Introduction

This chapter continues with the second research theme outlined in chapter 1 (p. 5). In Chapter 5, I outlined the development of the School Science Attitude Survey instrument and demonstrated its robustness and utility in Chapter 6. The article presented in Chapter 6 described how students' attitudes across the seven constructs of the attitude profile change on the broad scale during Years 7 and 8 for science, mathematics and design technology. In particular I showed that the constructs of enjoyability, relevance and enrolment intentions appeared intertwined and co-dependent on each other. In order to investigate these linkages further, it is important to probe more deeply into the longitudinal attitude data and align this with the qualitative data also obtained through the survey. This may then offer insights into the nature of the linkages between these attitudinal constructs.

The article presented in this chapter makes use of the same generalised version of the School Science Attitudes Survey as Chapter 6. The resulting analyses of the data are fundamental to forming an understanding of RQ7 and RQ8. More specifically, the longitudinal data analyses presented here are able to describe how students' attitudes of relevance and enjoyability towards science change and develop through Years 7 and 8 (RQ7) while the qualitative data analyses are able to impact of some common influences on student attitudes and future enrolment intentions within science (RQ8).

This article first places my research into the context of measuring science attitudes by considering the some of the key findings of science attitudes studies from the past three decades (e.g., Blackley & Howell, 2015; Osborne, Simon, & Collins, 2003; Potvin & Hasni, 2014; Simpson & Oliver, 1990). I then argue that the one of the common findings from this corpus of research—that student attitudes to science steadily decline with years spent in school—requires further, deeper investigation.

In Chapter 6, I outlined how two attitudes towards science for Year 7 students in particular appeared to correlate strongly with students' enrolment intentions on the macro scale. This article digs deeper into the Subject Attitude Profiles developed in Chapter 5 and investigated in Chapter 6, and considers how these attitudes change for groups of students over the first two years of high-school. Longitudinal k-means clustering, using a technique developed by Genolini & Falissard (2010), allows groups of students with similar attitude trajectories to be identified and analysed. Furthermore, computer assisted qualitative data analysis allowed students' comments and explanations to be associated with particular attitude trajectories resulting in the production of network graphs indicating the nature and degree of linking between various influences and student attitudes.

The resulting insights made available through this integrated approach to the longitudinal data offer unique perspectives on the issue of students' attitudes towards science. I show that while factors such as student sex and school type and location have been shown to influence students' attitudes at the broad scale (see Chapter 6), when students are allocated to smaller group level attitude trajectories these factors have no statistically significant effect. Furthermore, I show that positive enrolment intentions are more closely interrelated with enjoyability and relevance than negative enrolment intentions. That is to say, deliberately targeting the large number of minor influences affecting students' negative enrolment intentions may be useful for bolstering participation in science, but addressing a small number of key influences may result in positive attitude changes towards enjoyability, relevance and enrolment intentions simultaneously.

7.2 Journal Article 5

At the time of submission for examination, this article has not yet been submitted for peer review.

A longitudinal analysis of student attitudes of enjoyability and relevance towards school science across the first two years of Australian high-school.

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Research in science education has consistently shown that students' attitudes towards school science decline as they progress through high-school. Research has also shown that a lower percentage of Australian students are choosing to study science in the post-compulsory years of schooling. This article examines the changes in student attitudes towards the relevance and the enjoyability of school science in New South Wales over the first two years of high-school using longitudinal attitude trajectories. These data are then analysed alongside qualitative comments from the students which offer insights into the observed trends. We find that attitudes of enjoyability and relevance are highly interrelated with students' enrolment intentions. While previous studies have shown that overall changes in attitudes are linked with factors such as student sex and school type and location, we have found that within each attitude these same factors are unable to offer statistically significant explanation for the allocation of students to the different types of attitude trajectory. Finally, we identify a number of factors that are highly linked with the formation of attitudes towards enjoyability, relevance and enrolment intentions that offer potential for further research.

Introduction

Research since the 1970s has consistently argued that students' attitudes towards school science tend to decline over the first few years of high-school (e.g., Gardner, 1975; Ormerod & Duckworth, 1975; Osborne, Simon, & Collins, 2003; Osborne, Simon, & Tytler, 2009; Potvin & Hasni, 2014a; Simpson & Oliver, 1985, 1990). This same body of research has indicated that these declines are observed in many jurisdictions around the world (e.g., Sjøberg & Schreiner, 2010). However, many of these authors (e.g., Barmby, Kind, & Jones, 2008; Jenkins & Nelson, 2005; Lyons & Quinn, 2010; Simon & Osborne, 2010) note that students' attitudes towards *real* science more widely—that is the societal and technological aspects and implications of science—tend to remain more stable in many cases.

In recent years, significant discussion in Australian Government circles (e.g., Commonwealth of Australia, 2015b; Lowe, 2014; Office of the Chief Scientist, 2013; Prinsley & Baranyai, 2015) has revolved around the continued declines in participation in post-compulsory Science, Mathematics, Technology and Engineering [STEM] courses (Kennedy, Lyons, & Quinn, 2014; Kennedy, Quinn, & Lyons, 2018a) both in upper high-school and at the tertiary level. These STEM disciplines have been claimed as the new driving force for the Australian economy for the coming decades (e.g., Commonwealth of Australia, 2015a; Deloitte Access Economics, 2014) and much has been made of the need to produce more STEM-skilled students in Australian high-schools (e.g., Education Council, 2015; Office of the Chief Scientist, 2014, 2016; Prinsley & Baranyai, 2015). A number of researchers (e.g., Gardner, 1975; Kennedy, Quinn, & Lyons, 2018b; Ormerod & Duckworth, 1975; Osborne et al., 2003, 2009; Potvin & Hasni, 2014b; Simpson & Oliver, 1990) have identified potential links between students' attitudes and their enrolment decisions or intentions, yet the nature of these links—that is their causality or inter-relatedness—is unclear and on occasions disputed.

Kennedy et al. (2018b) showed that the range of attitudes towards science, mathematics and technology subjects as expressed by Year 7 high-school students in Australia were very wide and varied. This research indicated that both male and female students tended to begin secondary schooling with very similar attitudes towards school in general, but that these changed rapidly in some attitudinal aspects towards the different STEM disciplines. Furthermore, students' attitudes towards each of the individual STEM disciplines were notably different and also changed in different ways over the first year of high-school.

This paper builds on that study examining the changes in two specific attitudes towards school science over the first two years of high-school namely, enjoyability, and relevance. These attitudes are the focus for this paper as they were found to show meaningful inter-correlations with each other and with students' enrolment intentions, as well as demonstrating strong relative effect sizes (Kennedy et al., 2018b, pp. 15–17). The analyses presented in this paper additionally look at the types of attitude trajectories—that is the nature of the changes in attitudes over time—and connect these with some of the common explanatory themes offered by the students themselves.

Student Attitudes

One of the most marked commonalities of the attitudes research (Blackley & Howell, 2015; Blalock et al., 2008; Osborne et al., 2003; Potvin & Hasni, 2014b; Simpson & Oliver, 1990) has been the lack of a coherent, consistent, and incommutable working definition for the concept of attitude. Simon and Osborne (2010, p. 239) go so far as to note that the research field, as mature as it is, remains "bedevilled by a lack of clarity about what attitudes to science are". The potential for distilling general relationships from the vast array of literature has therefore often been hindered by these varying concepts of "attitude". Kind, Jones and Barmby (2007, p. 873) attempted to address this confusion, and defined an attitude as "the feelings that a person has about an object, based on their beliefs about that object". This definition of attitude is used in this paper where the *object* will be considered to be the school science course studied by the students.

Given this definition of attitudes and the assumed links between attitudes towards science, science enrolments, and future prosperity outlined above, it is important to understand how, when and why these student attitudes might change over time. Potvin and Hasni (2014b) conducted a systematic review of the attitudinal literature and observed that students' interest in science and technology at school clearly declined with years spent in school. These clear declines in positive attitudes towards science are echoed in the conclusions of other key research. Osborne, Simon and Tytler (2009), in their update to their previous literature review (Osborne et al., 2003), conclude that by age 15, science often fails to engage students at school to the same extent as other subjects even though upper-primary aged students (10 years-old) report high levels of interest in the subject. Potvin and Hasni (2014a) examined 21 articles from ten countries in which declining attitudes towards science and technology were reported. These studies showed that in almost all cases, the reported declines in attitudes were unambiguously negative over time, even when considering the transition between primary and secondary school.

The corpus of research clearly points to a shift in attitudes as students enter high-school. Barmby et al. (2008) found that students do not perceive school-science as being practical or relevant to their everyday lives. They also argued that the methods of learning and explanations given by teachers were often unhelpful in developing an understanding of the significance of science. Krapp and Prenzel (2011) found that pedagogical factors had a greater negative-influence on students' attitudes towards the physical sciences as compared with the biological sciences. Tytler, Osborne, Williams, Tytler, and Cripps Clark (2008) maintain that one of the more significant inhibitors of positive attitudes towards science and mathematics engagement by students is related to concepts of identity. They argue that to appeal to young people and convince them that the STEM subjects are worthy of their personal investment, the curriculum content needs to be recast so as to become more relevant and meaningful to the students themselves. Some researchers (e.g., Sjøberg & Schreiner, 2005) have even linked the declines in attitudes towards science to cultural shifts within advanced societies. However, many of these same researchers (e.g., Barmby et al., 2008; Krapp & Prenzel, 2011; Potvin & Hasni, 2014b) have shown that although students' attitudes towards science decline over time their attitudes remain pliable. In fact Potvin and Hasni (2014b) argue that attitudes can be favourably improved through the use of judiciously targeted, well-resourced efforts by well-informed educators.

In an earlier study (Kennedy et al., 2018b), we adopted an approach that reported students' attitudes towards science in comparison to their attitudes towards the academic aspects of school more generally. We showed that Australian year 7 high-school students' (age 12-13 years old) attitudes towards science remained stable throughout the first year of high-school in many aspects and even increased slightly with regards to enjoyability. However, we also noted that female students enjoyability ratings changed by less than those of their male peers. Strong correlations were also found between both enjoyability and relevance of school science with intentions to continue with the study of science, suggesting the a possible influence of these two attitudinal constructs on forming students' future intentions towards science.

Rationale and Research Questions

Attitudes are multifaceted and difficult to measure. Many attempts have been made to measure students' attitudes towards various aspects of schooling, including science classes (e.g., Blalock et al., 2008; Fraser, 1982; Kennedy, Quinn, & Taylor, 2016; Kind et al., 2007) each of which has provided a different insight into our understanding. However, there are a number of common themes that run through the educational research in this area. The School Science Attitude Survey [SSAS] developed by the first author (Kennedy et al., 2016) measures six of these common attitudinal constructs related to enjoyability, perceived difficulty, perceived self-efficacy, relevance, and usefulness for both careers in the science fields and in the student's own personal career. In addition, a seventh attitudinal construct relating to a student's intentions to enrol in science-based courses in post-compulsory education is also measured. These seven constructs make up what is known as a student's Subject Attitude Profile [SAP] (see Kennedy et al., 2018b, 2016) that allows a student's attitudes towards science to be compared with their attitudes towards other subject areas on the same basis. The primary advantage of the SSAS over other tools is its digital nature that allows for quick administration of the instrument and the longitudinal tracking of students over time.

Kennedy et al. (2018b) reported the changing attitudes of year 7 students in the areas of science, mathematics and design technologies. This paper looks at how the constructs of enjoyability and relevance, as applied to Australian high-school science courses, change for students over their first two years of secondary school and examines some of the explanations offered by students for these changes. In particular, this article addresses four main research questions:

1. How do students' attitudes of enjoyability and relevance of school science change as they progress through Year 7 and Year 8 of high-school?
2. What is the nature of any relationship between enjoyability, relevance and intention to enrol in science subjects in post-compulsory education for students in Year 7 and 8?
3. Do student and school-based factors, such as student sex and school location, impact the enjoyability and relevance of school science through Years 7 and 8?
4. What explanations do students offer for their changing attitudes of enjoyability and relevance in relation to school science through Years 7 and 8?

Methodology

This study sits within a post-positivist paradigm, and investigates different attitudinal constructs using a psychometric approach. Between 2014 and 2017, a total of 363 students provided the data used for these analyses. The students—who were in their first year of high-school (Year 7, age 12-13 years) at the outset of their participation— were drawn from 17 independent schools, one Catholic systemic school and one government school from across New South Wales. Seven of these schools were single-sex while twelve were co-educational. The majority (13) of these schools were located in the Sydney metropolitan area, with four in regional centres and two in rural settings. Schools and student participants voluntarily opted-in to provide data, with the over-representation of independent schools being an unintended consequence of this convenience sampling approach.

The Instrument

A web-based survey instrument—the SSAS (Kennedy et al., 2016)—was utilised to investigate students' attitudes to school subjects over time, including enjoyability and perceived relevance of school science which are the focus of this paper. As described in Kennedy et al. (2016), the SSAS is designed to combine attitudinal measurements with preference ranking techniques such as those developed by Whitfield (1979). This allows for a valid comparison of student attitudes towards science with their attitudes towards other subject areas. The instrument records a student's responses to items associated with the seven attitudinal constructs identified above. These measurements are made across all of the student's various school subjects at regular intervals—ideally once per term—during the first two years of high-school. As a result, a composite attitude rating [CAR] and a subject attitude rating [SAR] can be constructed for each measurement point, which represent each attitudinal construct for school subjects generally [CAR] and science in particular [SAR]. Further details of the SAR and CAR are outlined in the data analysis section.

Data Collection Procedures

Students were invited to access the instrument four times a year by e-mail. A unique random identifier was used track students' responses throughout Year 7 and 8 thereby facilitating longitudinal analysis of the data. The instrument was personalised by the student on first login so that only the subjects they studied were incorporated into the subsequent pages. Some additional demographic data, such as student sex and school location and type, were also captured at first login. Students rated each of the seven attitudinal constructs for each of their school subjects using semantically differentiated visual analogue scales. This resulted in a number between -50 and +50 being recorded in the system. Each page of the instrument presented students with questions relating only to a single attitudinal construct so as to collect data at a single point in time while providing the tools to collect data for all of their school subjects on the same page. Students were naturally able to rate each subject relative to their others. For the first wave of data collection all scales were initialised to a value of zero. For subsequent waves, each slider was initialised for each subject to the student's previous rating. This enabled students to only change the ratings for those scales which they felt had changed from the previous term. In addition to the quantitative data collected, the instrument also offered—but did not require—students the opportunity to add clarifying qualitative data explaining their change in attitude.

Data Analysis

The data in this paper consist of both quantitative student rating scores, as measured using the visual analogue scales of the instrument previously described, and verbatim comments that were optionally contributed by students through this same instrument. Student comments were collected as free text input and limited to 150 characters by the instrument software while raw rating scores were captured on a linear, unmarked scales from -50 to +50. The R statistical computing environment (R Core Team, 2018) was used to perform both the quantitative and qualitative analyses.

Quantitative data analysis

Attitude Measures

As highlighted by previous research (Kennedy et al., 2018b; e.g., Osborne et al., 2009; Potvin & Hasni, 2014a; Tytler et al., 2008), students' attitudes towards science are not unidimensional and cannot exist in isolation from one another. Therefore, it is essential to treat the attitudes of enjoyability and relevance as being separate, yet interlinked, aspects of a student's attitudinal profile. By extension, it is unreasonable to expect a student's attitudes towards science to exist apart from his or her attitudes towards other subjects studied at school. Therefore it is appropriate to determine a student's CAR towards a *single* attitudinal construct across all school subjects studied. The CAR is determined by averaging the student's individual attitude ratings for each school subject for each attitudinal construct and weighting this average by the relative amount of time allocated for each subject in a student's timetable. As described in Kennedy et al. (2018b), the utilisation of this weighted mean is appropriate and consistent with the theory of reasoned action (Fishbein & Ajzen, 2011). This novel and original approach to measuring students' attitudes towards all of their school subjects and determining a weighted mean rating for each attitudinal construct in essence serves as a proxy measure of students' general attitudes towards the academic aspects of school. The use of these CARs therefore allows for a more balanced picture of a student's attitudes towards academic school life as a whole to be formed and consequently, the CAR acts as a set of baseline measures against which

SARs may be compared. At the same time this approach addresses some of the limitations related to data transferability identified with other instruments (e.g., Abu-Hilal, 2000; Fraser, 1982; Gable & Roberts, 1983; Kind et al., 2007). The CAR ($\bar{x}$) of an individual student (*i*) for a particular attitudinal construct (*A*) measured at a given time (*t*) is given by the relationship:

$$\bar{x}_{iAt} = \frac{\sum_{S=1}^{n_S} N_S \cdot x_{iSAt}}{\sum_{S=1}^{n_S} N_S}$$

Where:
$\bar{x}_{iAt}$ is the individual's mean composite attitude rating
N_S is the number of lessons assigned to subject S per timetable cycle
x_{iSAt} is the student's raw rating from -50 to 50 determined using the visual analogue scale

A student's science SAR can thence be determined by subtracting their CAR from their raw science rating score. This extends the potential range for a SAR to -100 to +100, although this range would likely be much narrower in the majority of cases. For the purposes of interpretation, the SAR can be used to categorise student attitudinal strengths into one of seven descriptive categories that are given in Table 7.1.

Table 7.1: The relative strength of attitudes toward science as categorised by a student's Subject Attitude Rating [SAR]

Minimum SAR	Maximum SAR	Attitudinal Strength
-100	-50	Very Strong Negative
-50	-30	Strong Negative
-30	-10	Weak Negative
-10	+10	Neutral
+10	+30	Weak Positive
+30	+50	Strong Positive
+50	+100	Very Strong Positive

Attitude trajectories

Previous research has also shown that students' attitudes tend to change over time. A previous paper (Kennedy et al., 2018b) reported on the attitudes of Year 7 students towards science at the group level—for example comparing male and female students. This paper complements that by reporting data from the same cohort of students tracked across the first two years of high-school (Years 7 and 8) analysed at the sub-group or cluster level. The advantages of this approach, compared to higher-level group analysis, lie mainly in the ability to investigate the differences in effects, if any, of potential influences—such as student sex or school type—on different sub-groups of students for a given attitudinal construct. In this context, the null hypotheses are that there are no statistically significant influences from the potential predictor variables on the measures of attitudes for each of the sub-groups of students' established for each attitudinal construct. That is to say, the potential influences impact on the attitude trajectories for small groups of similar students in statistically similar ways for the given attitudinal construct.

In the analyses presented here, we produced spaghetti plots of individual student's SARs and CARs for both enjoyability and relevance, then clustered these individual plots into attitudinal trajectories and compared them descriptively. For the purposes of interpretation, the shape of the attitudinal trajectory can be used to categorise changes in student attitudes into one of nine broad, descriptive categories that are given in Figure 7.1. We then investigated whether these attitudes changed over time, and tested the significance of any apparent influencing factors on attitude trajectories for the individual attitudinal constructs via one-way ANOVAs. Quantile-quantile plots were used to check that these data exhibited adequate assumptions of normality.

The technique of k-means clustering (Jain, 2010) is frequently used in data mining analyses to separate large numbers of observations into clusters that can then be described by a set of simpler mean scores. Traditional k-means clustering cannot easily be applied to longitudinal data, such as collected in this study, as the standard algorithms are not able to ensure that students do not change from one cluster to another over time. Genolini, Alacoque, Sentenac and Arnaud (2015) developed a technique specifically to apply the k-means clustering approach to longitudinal data. The developed algorithms (Genolini et al., 2015) allow data described by one variable (*kml*) or multiple variables (*kml3d*) to be described in terms of general trends known as trajectories. An example of this approach for the Enjoyment CAR is shown as Figure 3. In the context of our attitudinal analysis, we call these general trends Attitude Trajectories [AT]. A solution that maximises the clustering condition and remains interpretable is considered to be the optimum clustering solution for the plotted trajectories. Individual students can then be linked to their respective ATs for further analysis. It is important to note that the *kml* algorithm can yield clustering solutions that are only of an exploratory nature (Genolini & Falissard, 2010). A one-sided chi-squares analysis can be used to determine if the assignment of students to the identified trajectories is significantly different from a random distribution, however, the non-model-based approach of k-means clustering for longitudinal data means that there are no suitable techniques to statistically test the nature of any identified differences.

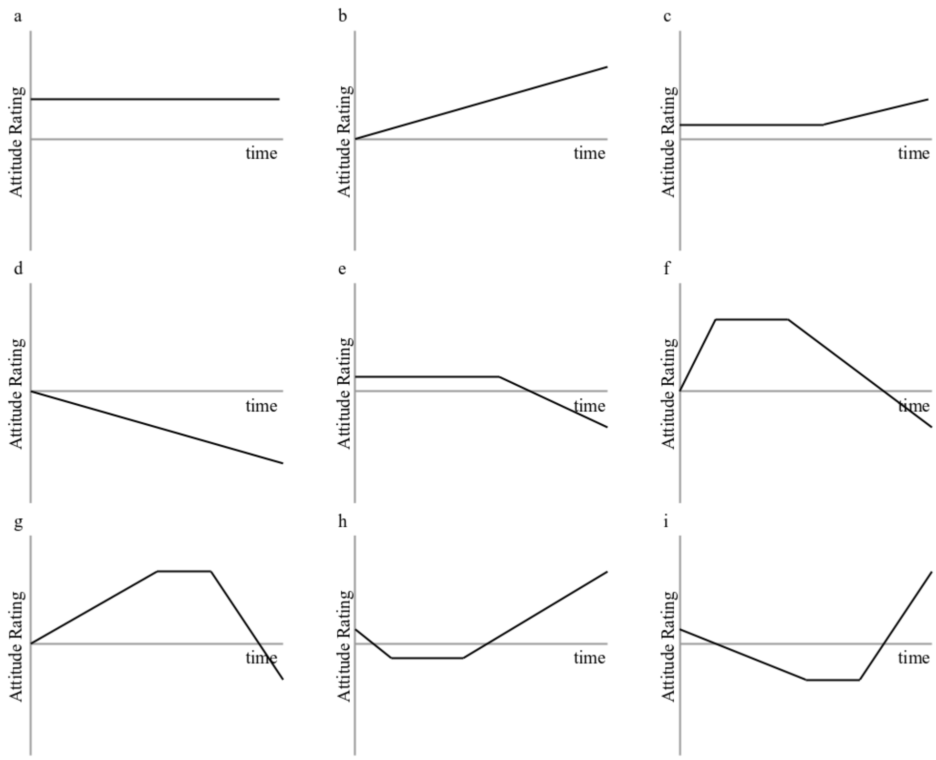

Figure 7.1: Idealised shapes of student attitude trajectories.

(a) flat, (b) rising, (c) up-turning, (d) declining, (e) down-turning, (f) early-n-shaped, (g) late-n-shaped, (h) early-u-shaped, (i) late-u-shaped. Note that the vertical positions of the trajectory is independent of its shape.

Multinomial logistic regression (Venables & Ripley, 2002), was utilised to explore the effects of student sex, school location (metropolitan, regional or rural) or school type (single sex or co-educational) on the allocation of specific students to particular ATs. This process detected no statistically significant differences between the allocation of students across these categorical variables. That is to say, the effects of these categorical variables on students' attitudes at the group level is not statistically different from their effects at the sub-group level. Given the limitations imposed by the sample size on the power of the regression analysis, coupled with the exploratory nature of k-means clustering, it is important to note that this does not imply that there are no differences between the ATs.

Qualitative Analysis

As part of the data collection process, students optionally contributed a short qualitative comment that explained their reasoning for changing their rating for a particular subject and attitude by more than 15 points from their previous rating (or from zero in the case of first round ratings). These explanatory comments were intended to provide insight into a student's reasoned changes with regards to a specific change in attitude. However, during the analysis it was found that while these comments were specific to the school-subject of interest, they were not tightly focussed towards a single attitudinal construct (i.e. an explanatory comment saved against difficulty may have made reference to the relevance of the subject). Therefore, each student's comments relating to science across all attitudinal constructs were collected for analysis.

All comments were entered into RQDA (Huang, 2018), a qualitative data analysis package for the R statistical environment. Individual comments were then attributed to a given student ID and demographic factors such as school type, student sex, and school location (metropolitan, regional or rural) were attached. Each comment was then coded, using a combination of descriptive and in vivo methods as described by Saldaña (2014), resulting in an evolving codebook. Codes were subsequently clustered based on similarity forming categories from which key themes emerged.

Finally, student IDs were cross-referenced and matched to the ATs described by the quantitative analyses, so their qualitative data could be examined for potential explanations for the shapes of the ATs. These explanations are elaborated within the results sections for each attitudinal construct.

Network Diagrams

The coded explanations from the qualitative analysis were mapped so as to create network diagrams. In each of these diagrams the attitudinal construct of interest (e.g., enjoyability) is composed of two or more attitudinal positions (e.g., unenjoyable and enjoyable). Each of these positions is associated with the codes that emerged from the qualitative analyses by a directed link. The direction of the link points away from the position towards the code and can be considered to represent the phrase "*position* is linked to and influenced by *code*".

As attitudes do not form in isolation from one another, the paths between each attitudinal position are of particular interest. These number of paths, while not indicating a direction of causality, indicate the degree of inter-relatedness of those positions. Paths can be either direct (i.e. one attitudinal position is used by students to directly explain their attitude towards another position) or indirect via a common code. Therefore, codes that describe an experience, belief or understanding that are linked to more than one attitudinal position must be considered to be more influential to the overall formation of attitudes than codes that are linked to only one attitudinal position. In the simple network models used in these analyses, a code with 5 links will support T_{5-1} paths while a code with 3 links will support T_{3-1} paths (i.e. a code with 5 links supports 4+3+2+1=10 paths while a code with 3 links supports 2+1=3 paths). It is important to note that a network diagram does not indicate the frequency with which links are formed by students but simply indicated that links are made between the code and the attitudinal position.

Results

In this section we consider the attitudinal constructs enjoyability and relevance of school science (i.e. SARs), and also the corresponding composite ratings for these same attitudinal constructs in relation to the academic aspects of school in general (i.e. CARs). For both of the enjoyability and relevance constructs, the trajectories (ATs) derived from the k-means clustering of the SARs and CARs will be considered individually, and then the interactions and commonalities between SAR and CAR trajectories will be presented. We then present network diagrams showing the themes from the coding of student explanations for their changed ratings of the enjoyability and relevance of school science, and a network diagram showing the relationship of these constructs with each other and with enrolment intentions.

Enjoyability

The student enjoyability CARs towards school are generally rather positive throughout Year 7 and into Year 8, although there is large variation between individual students. Figure 7.2 (upper panes) shows a slight variation between male and female students in terms of CAR over this period but a one-way ANOVA shows that this is not statistically significant. Male students additionally exhibit a degree of seasonality in their CARs, with semester 2 ratings generally lower than the preceding semester 1 rating on average.

The science SARs for Enjoyability (Figure 7.2 lower pane) show a narrower range of ratings for male students than is seen in their CARs, while the ratings for female students are marginally wider than the corresponding CARs. However, in general there is less variation in the science SARs over time for both sexes although the seasonality seen in the male CARs is still visible in the science SARs.

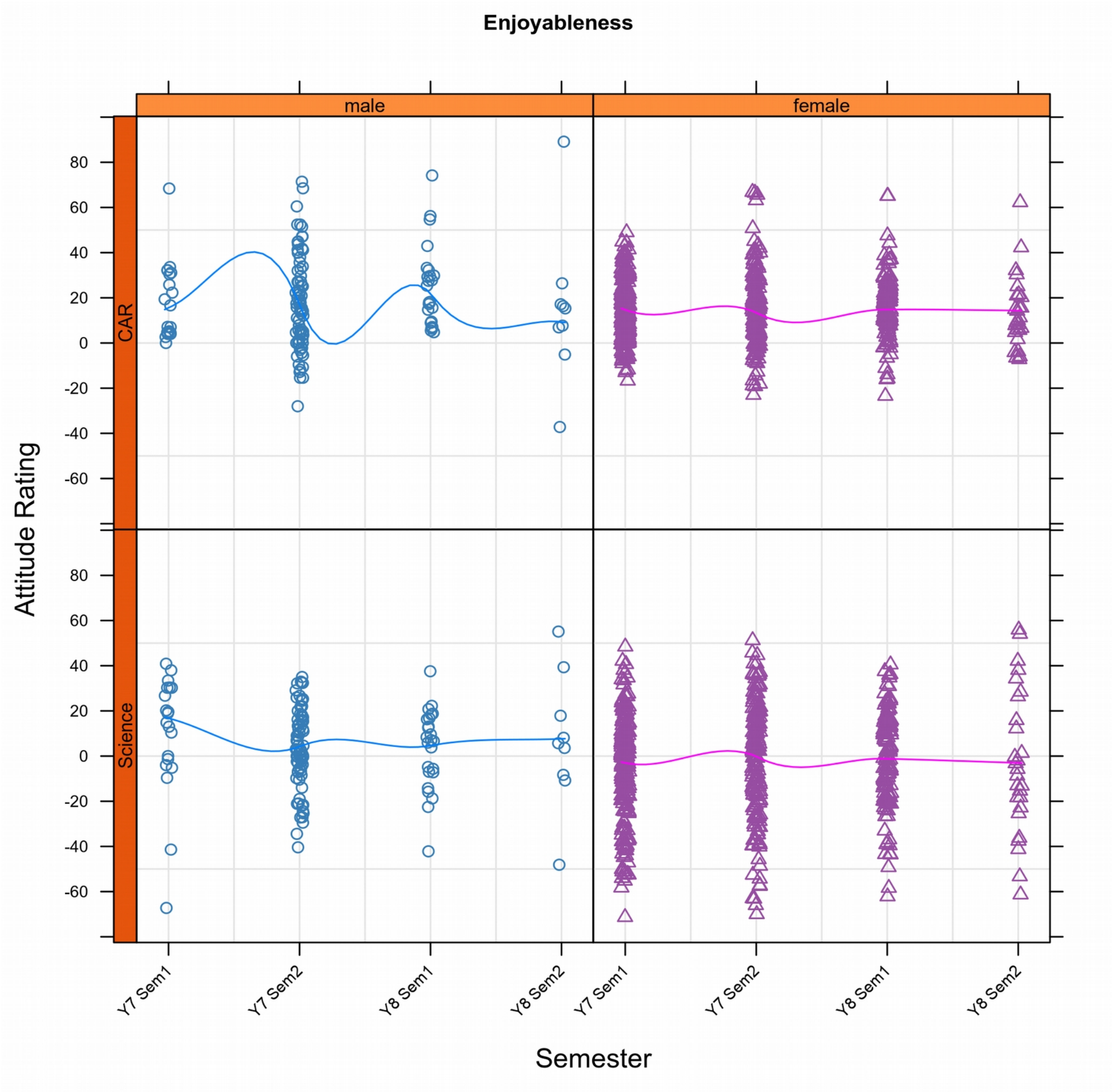

Figure 7.2: Longitudinal Plots of Student enjoyability Composite Attitude Ratings (upper), and science Subject Attitude Ratings (lower) over the first 2 years of high school split by student sex.[i]

Attitude trajectories for enjoyability CARs

A k-means longitudinal cluster analysis of the trajectories of the individual students reveals three distinct longitudinal trends (Figure 7.3) within the CARs for enjoyability. A chi-square test of goodness-of-fit was performed to determine whether the three ATs were equally likely for the students in this sample. Assignment to the the three ATs was not equally distributed in the sample, χ^2 (2, n=176) = 27.42, p < .001. The proportions of students assigned to each trajectory (cluster) organised by student sex, school type and school location are shown in Table 7.2. As can be seen, female students appear least

2 The LOESS line is based on a parabolic function that makes use of the local values of attitude rating at a point in time and is calculated based on the underlying data not the displayed means.

commonly assigned to trajectory C while male students are slightly more frequently assigned to trajectory C than to A or B. Students in boys' schools appear to be least commonly assigned to trajectory B, those in girls' schools are most commonly assigned to trajectories A or B, while those in co-educational schools are assigned to trajectories A or C with approximately the same frequency. Students in metropolitan schools are least frequently assigned to trajectory C.

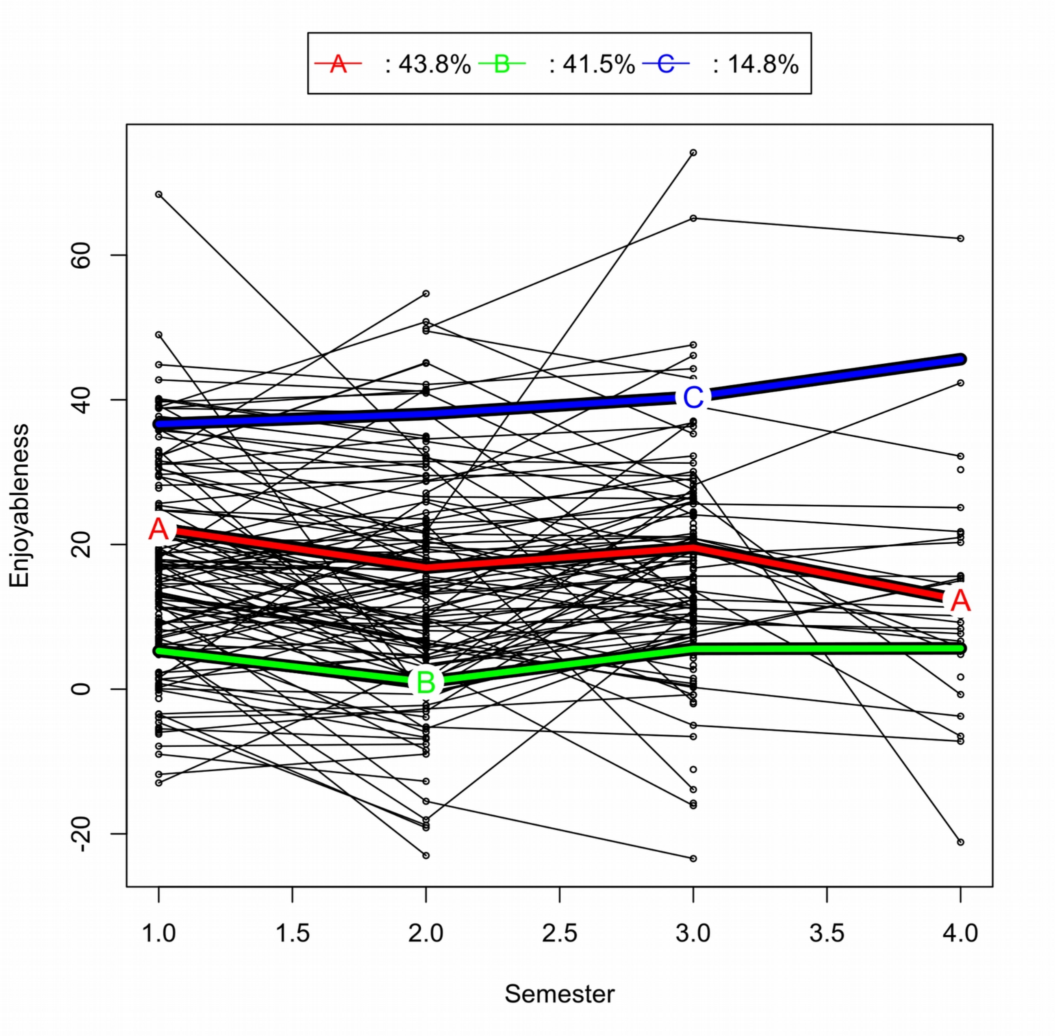

Figure 7.3: Longitudinal Trajectory Clustering for the Composite Attitude Rating for enjoyability. Three general trends[i] are visible in student attitudes towards enjoyability: A-weak-positive down-turning trajectory; B-neutral flat trajectory; C-strong-positive rising trajectory.

It is also apparent from Figure 3 that trajectories A and B show very similar shaped trends over the first 3 semesters of high-school. Students' enjoyability ratings towards school decline slightly over the first half of year 7 before rebounding to their original level

3 It should be noted that each AT in each analysis is assigned a letter code starting from 'A' in decreasing order of frequency and that there is no inherent linkage implied between two ATs for different attitudes with the same letter code.

by the beginning of Year 8. However, both trajectories remain positive overall during this period. Students on trajectory A then take a noticeable downturn in their enjoyability ratings during the second half of year 8. Students following trajectory C show an increasingly positive rating towards their composite rating for school enjoyability. These three CAR trajectories could be described—using the relative strength of attitudes described in Table 7.1 and the trajectory shape described in Figure 7.1—as neutral flat (trajectory B), weak-positive down-turning (trajectory A), and strong-positive rising (trajectory C).

Table 7.2: Percentage spread of students between general school enjoyability cluster trends based on student sex, school type and school location.[4]

Cluster	sex		School Type			School Location		
	F	M	Boys	Girls	Co-Ed	Metro	Regional	Rural
A	44.6	35.3	42.3	44.4	37.5	43.7	50.0	0.0
B	43.4	23.5	14.3	44.4	25.0	43.1	0.0	100.0
C	12.0	41.2	42.3	11.1	37.5	13.2	50.0	0.0

Attitude trajectories for enjoyability for the science SAR

A similar k-means cluster analysis of the longitudinal trends for the science SAR (Figure 7.4) reveals four trajectories labelled A to D. Again, a chi-square test of goodness-of-fit was performed to determine whether the four ATs were equally likely for the students in this sample and it was found that the assignment of ATs was not equally distributed in the sample, χ^2 (3, n = 176) = 22.09, p < .001. The proportion of students assigned to each trajectory, again sliced by student sex, school type and school location, are shown in Table 7.3. As can be seen, female students are more frequently assigned to trajectories A or B than C or D while male students are more commonly found on trajectories A or C. Students in all school types are most frequently found assigned to trajectory A. However, students from boys' schools or coeducational schools are also highly commonly found on trajectory C, while students in girls' schools are frequently found on trajectory B. Metropolitan students are frequently assigned to both trajectory A and trajectory B while regional and rural students are commonly found on trajectories A or C.

4 Note column totals may not add to 100% due to rounding

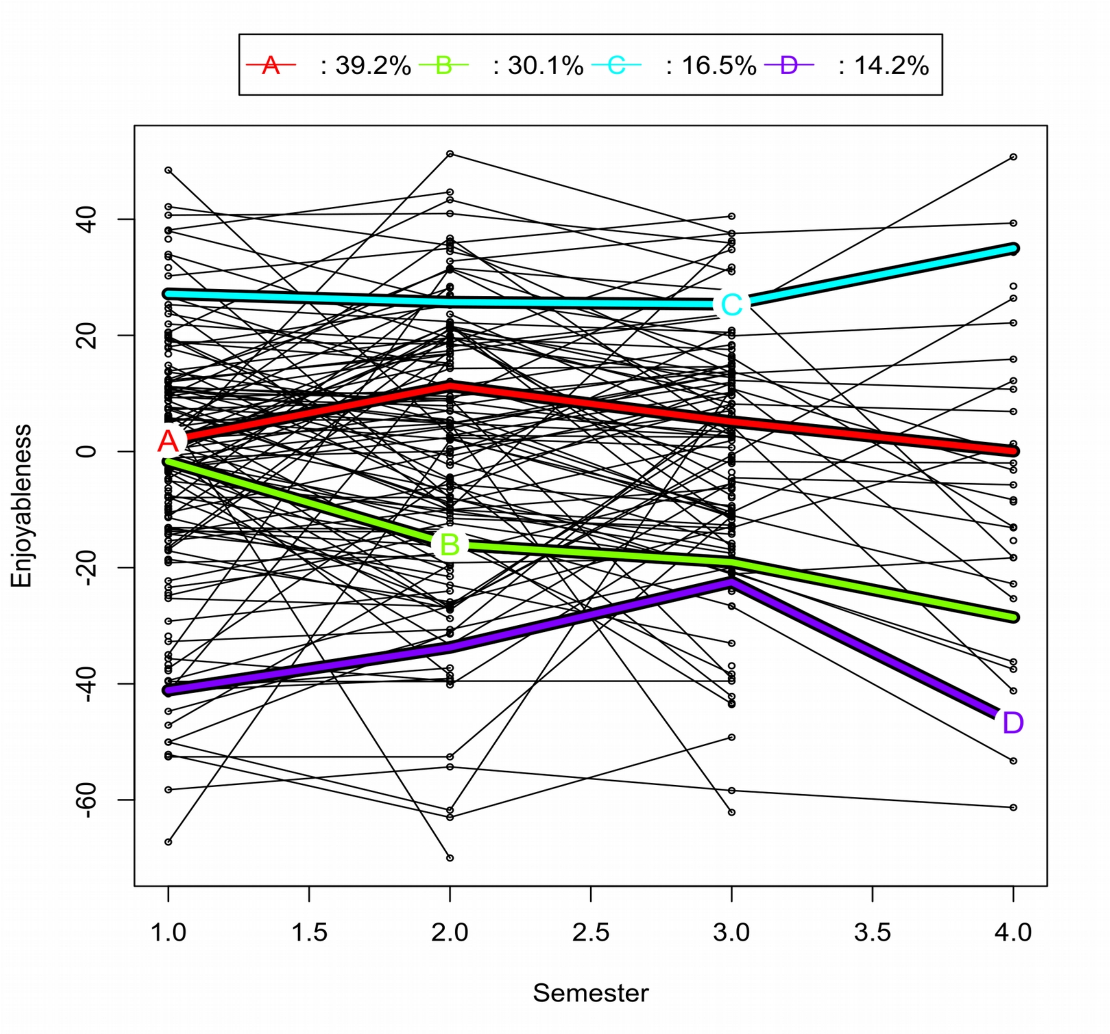

Figure 7.4: Longitudinal trajectory clustering for science student attitude ratings. Four general trends are visible in student attitudes towards enjoyability: A-neutral early-n-shaped; B-weak-negative declining; C-strong-positive up-turning; D- strong-negative late-n-shaped.

Students on trajectory A start from a neutral base-point (M=1.91, SD=12.9) during Semester 1 Year 7, and rise towards a peak at the end of Year 7. Their SAR for the enjoyability of science then declines steadily until the end of Year 8 when it returns to a neutral rating (M=0.05, SD=12.3). Students on trajectory B, start from a slightly lower base-point than A (M=-1.72, SD=12.8) and their SAR towards science enjoyability declines steadily throughout their first two years of high-school (M=-28.6, SD11.1) by the end of Year 8).

Trajectory C starts from a more strongly-positive base-point (M=27.2, SD=11.2) than the other trajectories and remains relatively flat until the middle of Year 8. By the end of Year 8, the mean SAR rose to 35.0 (SD=10.9).

Trajectory D is notably different from any of the other three clusters. Starting from a strongly-negative base-point (M=-41.1, SD=11.4) the cluster shows a steady rise throughout the early period of study to a peak of -22.5 (SD=19.5) at the mid-point of Year 8. This trajectory then shows a visible down-turn in attitudes reaching a final low of -46.6 (SD=18.9) at the end of year 8.

Table 7.3: Percentage spread of students between enjoyability cluster trends based on student sex, school type and school location.

Cluster	Sex		School Type			School Location		
	F	M	Boys	Girls	Co-Ed	Metro	Regional	Rural
A	39.6	35.3	42.9	40.5	25.0	39.5	37.5	0
B	30.8	23.5	14.3	32.0	18.6	31.1	12.5	0
C	14.4	35.3	42.9	13.1	37.5	15.0	37.5	100
D	15.1	5.6	0.0	14.4	18.6	14.4	12.5	0

Relationship between CAR and science SAR enjoyability ATs

In order to investigate any relationships between students' enjoyment of school science and their enjoyment of the school subjects in general, a clustered scatter plot (Figure 7.5) was produced. This shows the assignment of science enjoyability trajectories —assigned from students' science SAR—against the trajectories identified in the analysis of composite school enjoyability—the CAR. Each cluster in this diagram is referred to using a two letter tuple of the form [X,Y] where X is the composite rating trajectory code and Y is the science rating trajectory code. Considering male students only, it is worth noting the low plot densities for students who follow composite trajectory C and science trajectory C (henceforth referred to as combination [C,C]) and [A,B] as well as the higher plot densities for [A,A], [A,C] and [C,A]. For female students the unusual plot density in combination [C,A] and the relatively high densities in combinations [A,A], [B,A], [A,B], [A,C] and [B,B] are of some interest.

Male combination [C,C] suggests that students who report strong-positive up-tuning ratings of enjoyability towards the academic aspects of school in general throughout years 7 and 8 tend to also report strong-positive up-tuning ratings towards science. Similarly the combination [A,B] shows that students with weak-positive down-turning enjoyability ratings towards school tend to report neutral early-n-shaped enjoyability ratings towards science. These patterns may suggest that the enjoyability of school science and the enjoyability of the academic aspects of school more generally are strongly interdependent. However, there are few students in these two clusters, where science and composite enjoyability follow similar trends, and so this indication of positive linkage cannot be generalised to the wider population. Furthermore, considering the denser plot combinations [A,A]—weak-positive down-turning CAR rating but neutral early-n-shaped science SAR, [A,C]— weak-positive down-turning CAR and strong-positive up-turning science SAR, and [C,A]—strong-positive rising CAR with neutral early-n-shaped science SAR, it could be suggested that for the majority of the male students in the sample, attitudes to the enjoyability of science have no predictive influence on a student's attitude to the enjoyability of school more generally and vice-a. That is to say that for the majority of male students in this sample, the enjoyability of science and the enjoyability of school more generally are independent of each other.

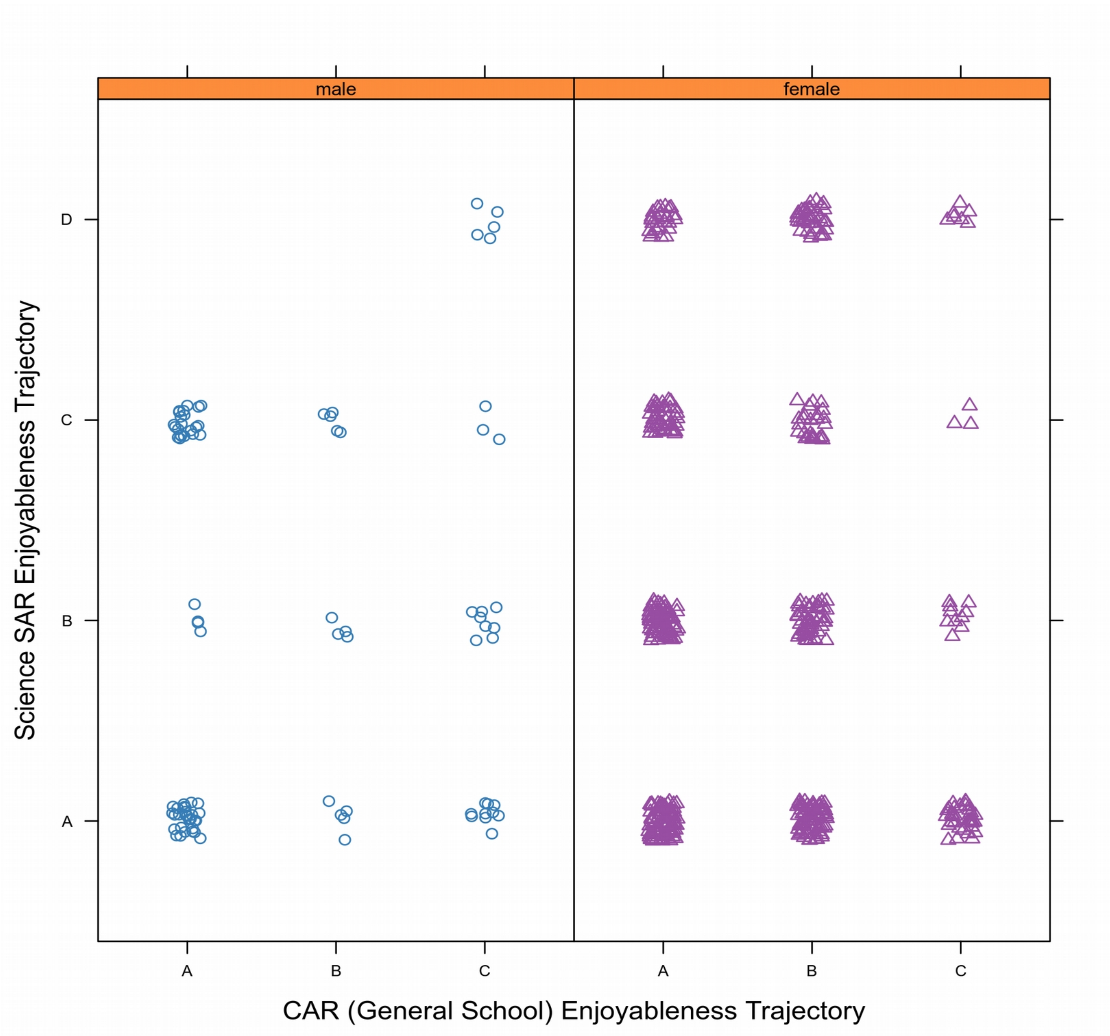

Figure 7.5: Plot of trajectories for composite attitude ratings of enjoyability versus science SAR enjoyability. The density of plotting points is indicative of the frequency of co-clustering.

Male students in combinations [C,C] and [A,B] offered explanations for their science rating scores such as “we get to do cool things [in science class]” $M_{C,C}$ or “I am in a much lower [science] class due to streaming” $M_{A,B}$. This suggests that first hand experiences may play an important role for male students in forming positive attitudes towards science enjoyability in schools, while their beliefs around their ability interact strongly with negative attitudes.

Female students who report a strong-positive rising CAR for enjoyability towards school in general (CAR trajectory C) are more frequently found on science trajectory A—neutral early-n-shaped—than any other[i]. That is, students who report a strong-positive rising enjoyability rating for school in general report an increase in science enjoyability at the beginning of Year 7 but this then falls away slowly over time but does not impact their overall enjoyability rating of school. This suggests that the cause of these students’ increase in composite enjoyability over the two years is unlikely to be due to their science lessons. A number of explanatory comments from students in this category made the link between enjoying science and achievement in science emphasising that for these students the nature of the learning is not as significant as the feeling of achievement in determining enjoyability. Typical comments included, “I like science and achieved an A for science in my report” $F_{C,A}$ or “Though we only started proper science this year in high-school, I have managed to get As and good marks in all my tests” $F_{C,A}$.

Female students on the two most common science trajectories (i.e. A—a short-term rise in enjoyability from a neutral level followed by a decline or B—a steady decline in enjoyability ratings from a weak-negative starting level) are most frequently assigned to the composite trajectories A or B which are associated with weak-positive to neutral ratings of enjoyability towards school[5]. A common theme apparent in the explanations offered by these students in relation to the enjoyability of science related to a lack of confidence in their own ability and especially around assessment marks. For example, “I think I am okay at science but the test wasn't too hard” $F_{A,B}$ or “I do OK in my assessments but perhaps I don't particularly understand everything” $F_{A,B}$.

5 It should be noted that these observations are not contradictory to one another but instead highlight the directional (or conditional) nature of interpreting these attitudinal relationships. These observations could be summarised as “if a student has a rising attitude rating towards the enjoyability of school in general then he or she is more frequently assigned to science trajectory A than to any other. However, if a different student is assigned to science trajectory A or B he or she is more frequently found on a neutral or declining composite trajectory.”

Student explanations for changing their science enjoyability rating

A network graph linking the coded forms of the explanations offered by students to their attitudinal positions in regards to their enjoyability rating is shown as Figure 7.6. This representation indicates the existence of links between the different attitudinal positions, shown in blue (unenjoyable vs enjoyable), of the enjoyability attitude construct and the students' coded explanations but does not directly indicate the strength of these links. The size of the code circle is indicative of the number of attitudinal positions to which that code is associated. This diagram shows that there is far less variation in student explanations for an attitudinal position of unenjoyable compared with the number of different explanations offered for enjoyable: the unenjoyable position is linked to 11 codes versus the 22 codes linked to the enjoyable position. Figure 7.6 also highlights the importance of six explanatory codes (shown in orange) that are associated with both the positive and negative attitudinal positions for enjoyability. These explanations are of particular interest because they describe influences that could sway a student's attitude away from unenjoyable and towards enjoyable or vice-versa. These key explanations focus on three general aspects. Firstly, self-focused explanations (coded as ability and achievement) around students' beliefs about their own ability and their personal experiences with regards to past achievement. Secondly, the influences of interpersonal relationships and in particular the role of the teacher in the classroom (coded as interpersonal relationships and teacher). Finally, the nature of the sub-discipline areas (coded as biology and subject areas) within school science which suggests that students may hold different attitudes towards the biological and physical sciences.

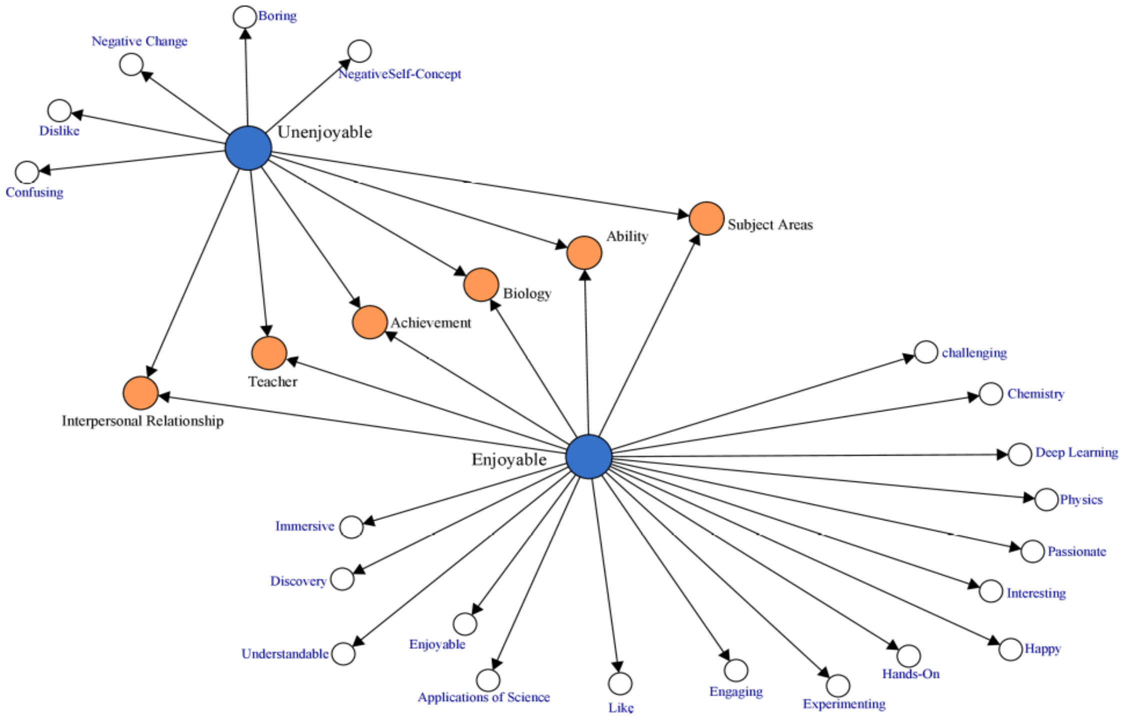

Figure 7.6: Network graph showing the links between coded students' explanations and the positive and negative attitudinal positions of enjoyability (blue circles).

The degree of linking of the coded explanations is indicated using colour; white indicates that a code is linked to either the positive or negative explanations of enjoyability while orange indicates that that concept has been utilised in both negative and positive student explanations.

Summary of main messages relating to students attitudes of enjoyability

The results above highlight four main points about Year 7 and 8 students' perceptions of the enjoyability of their school science experiences. These are:

- Students tend to follow one of four distinct attitude trajectories (Figure 7.4) related to the enjoyability of school science and the allocation of a particular student to one or another of these cannot be predicted reliably based only on student sex, school type or school location.
- In general, there is no clear correlation between male students' ratings of enjoyability of school science and enjoyability of school subjects in general.
- Female students who report strong-positive rising attitudes towards the enjoyability of school subjects in general tend to report an initial rise in attitude rating for school science but this falls away slowly over time. Hence, it appears that their enjoyment of school subjects in general is occurring despite, rather than because of, science and that they enjoy other subjects more.

- The influences that seem to relate most strongly to students' attitudes of enjoyability of science appear to centre around ability and attainment, the nature of the course content, or the nature of interpersonal relationships particularly with the teacher—as indicated by the orange circles in Figure 7.6 and the verbatim comments.

Relevance

The students relevance CARs towards school subjects in general are slightly positive in Year 7 and tend towards neutrality in Year 8. However, there is large variation between individual students, particularly in the second semester of year 7. Figure 7.7 (upper panes) shows very little variation between male and female students in terms of CAR over this period and one-way ANOVA shows that this is not statistically significant.

For male students ,the science SARs for relevance (Figure 7.7 lower pane) show a slightly wider range of ratings than their corresponding CARs—indicated by the greater plotting density around the mean seen in the CAR plot—while female students' relevance SAR ratings are noticeably wider than the corresponding CARs. However, while female ratings are on average steadily neutral for science, the LOESS line shows that mean male ratings are visibly more varied ranging between +20 and -20.

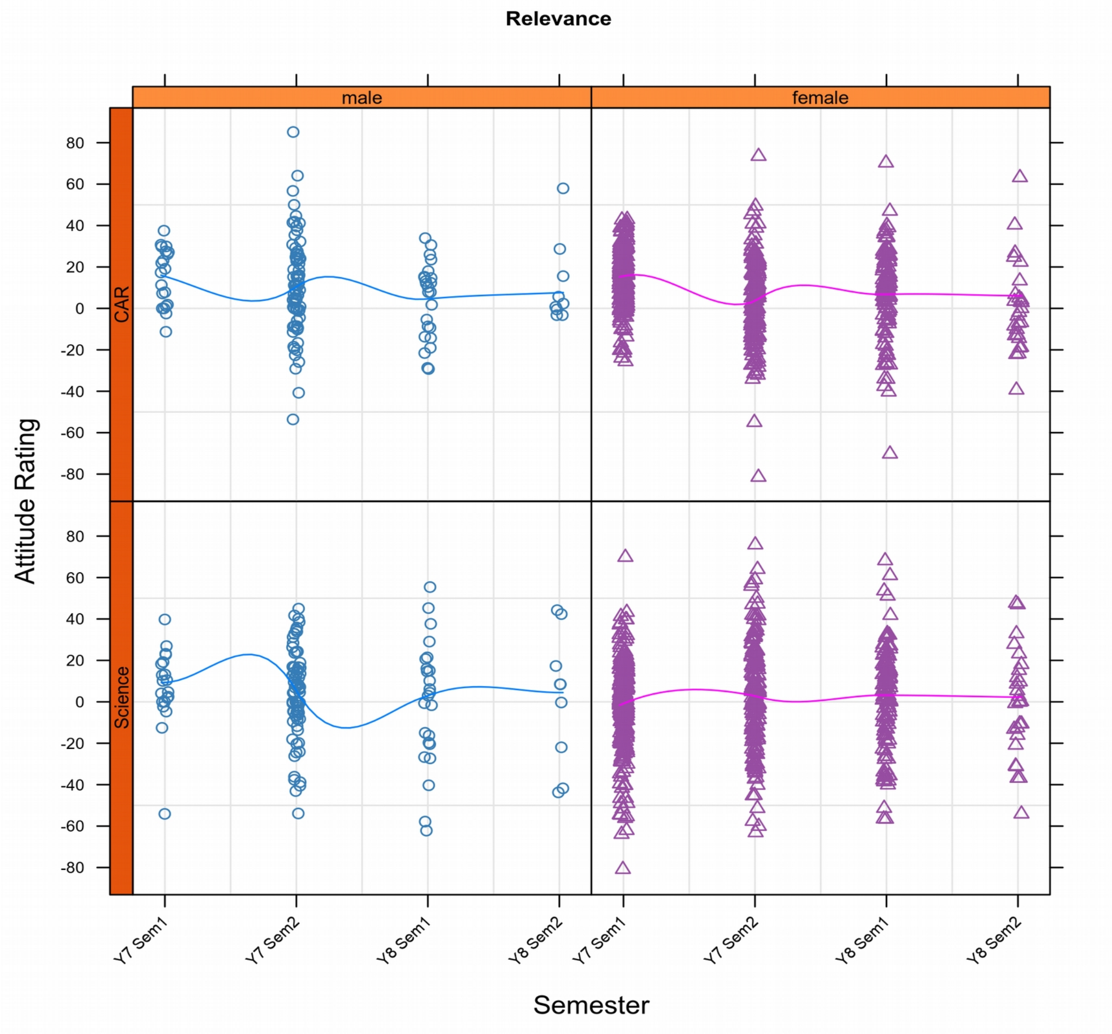

Figure 7.7: Longitudinal Plots of Student relevance Composite Attitude Ratings (upper), and science Subject Attitude Ratings (lower) over the first 2 years of high school split by student sex.

Attitude trajectories for relevance CARs

A k-means longitudinal cluster analysis carried out on the attitude trajectories of the individual students reveals four distinct longitudinal trends (Figure 7.8) within the CARs for relevance. A chi-square test of goodness-of-fit was performed to determine whether the four ATs were equally likely for the students in this sample. Assignment to the the four ATs was not equally distributed in the sample, χ^2 (3, n = 176) = 20.36, p < .001. The proportion of students assigned to each trajectory filtered by student sex, school type and school location is shown in Table 7.4. As can be seen, both female and male students are least frequently assigned to trajectory D while trajectories A, B and C have very similar frequencies for students of either sex. Students in boys' schools are slightly more frequently assigned to trajectory B, as are students in girls' schools. Students studying in co-educational schools are more commonly assigned to trajectory A than B or C, however, students in all school types are least frequently found on trajectory D. Finally, students in both metropolitan and regional schools show similar frequencies of being assigned to trajectories A, B or C.

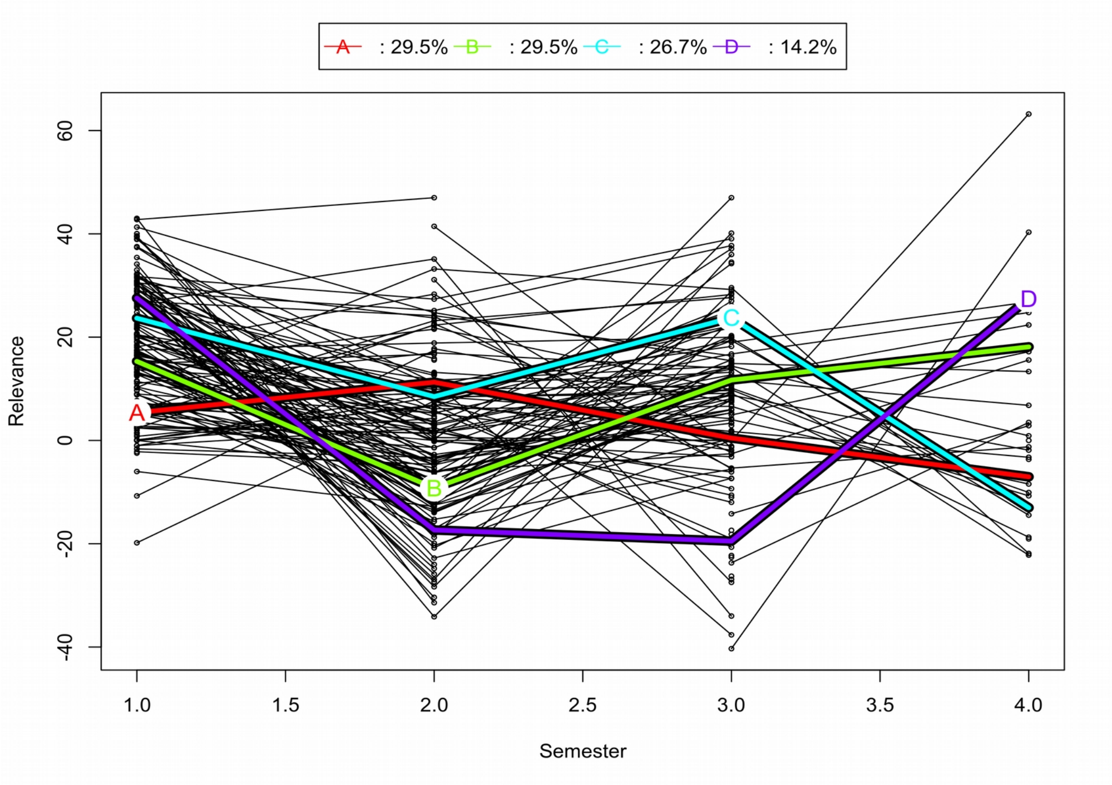

Figure 7.8: Longitudinal Trajectory Clustering for the Composite Attitude Rating for relevance. Four general trends are visible in student attitudes towards enjoyability: A-neutral early-n-shaped trajectory; B-weak-positive early-u-shaped trajectory; C-weak-positive roller-coaster trajectory; D-weak-positive deep mid-u-shaped trajectory.

Table 7.4: Percentage spread of students between composite school relevance cluster trends based on student sex, school type and school location.

Cluster	Sex		School Type			School Location		
	F	M	Boys	Girls	Co-Ed	Metro	Regional	Rural
A	28.9	35.3	28.6	28.8	37.5	29.3	25.0	100
B	29.6	29.4	42.9	30.1	18.8	29.3	37.5	0.0
C	27.0	23.5	28.6	26.1	31.3	26.3	37.5	0.0
D	14.5	11.8	0.0	15.0	12.5	13.8	0.0	0.0

It is apparent in Figure 8 that trajectories B and C show very similar trends over the first 3 semesters of high-school, albeit with C rating consistently higher than B throughout. In the second half of year 8, students on trajectory C take a sharp downturn in regards to their ratings of relevance of school while those on trajectory B continue to increase steadily. Students on trajectory A demonstrate a slight rise in ratings of relevance over the first semester of year 7 before steadily declining in their ratings over the remainder of year 7 and throughout year 8. Students on trajectory D show a very steep decline in ratings of relevance towards school in general over the first half of year 7 which then remain low until the second half of year 8 when they rebound back towards their original levels. These four CAR relevance trajectories could be described as neutral early-n-shaped (trajectory A), weak-positive roller-coaster (trajectory C), weak-positive early-u-shaped (trajectory B), and weak positive deep mid-u-shaped (trajectory D).

Attitude trajectories for relevance for the science SAR

A similar k-means cluster analysis of the longitudinal trends for the relevance of science SAR (Figure 7.9) reveals three trajectories labelled A to C. These relevance trajectories could be described as neutral flat (trajectory A), weak-negative early-n-shaped (trajectory B), and weak-negative late-u-shaped (trajectory C). A chi-square test of goodness-of-fit was again performed to determine whether the three ATs were equally likely for the students in this sample and it was found that assignment to the the three ATs was not equally distributed in the sample, χ^2 (2, n = 176) = 32.06, p < .001. The proportion of students assigned to each trajectory, again organised by student sex, school type and school location, is shown in Table 7.5. As can be seen, both male and female students are more frequently assigned to trajectory A than B or C. The remaining male students are more commonly found on trajectory B than on C, although this spread is more balanced for female students. Students in all school types are most commonly found on trajectory A, as are students in either metropolitan or regional areas. However, the remaining girls in single sex schools are fairly evenly distributed between trajectories B and C with B being slightly more common.

Table 7.5: Percentage spread of students between relevance cluster trends based on student sex, school type and school location.

Cluster	Sex		School Type			School Location		
	F	M	Boys	Girls	Co-Ed	Metro	Regional	Rural
A	44.0	70.6	71.4	43.1	68.8	44.9	87.5	0.0
B	30.8	23.5	14.3	31.4	25.0	31.1	0.0	100.0
C	25.2	5.9	14.3	25.5	6.3	24.0	12.5	0.0

Students on trajectory A start from a slightly positive base-point (M=11.3, SD=13.6) during Semester 1 Year 7, and decline towards a low at the end of Year 7 (M=-1.5, SD=16.2). Their SAR for the relevance of science then rises steadily until the end of Year 8 when it returns to a slightly positive rating (M=10.5, SD=15.0).

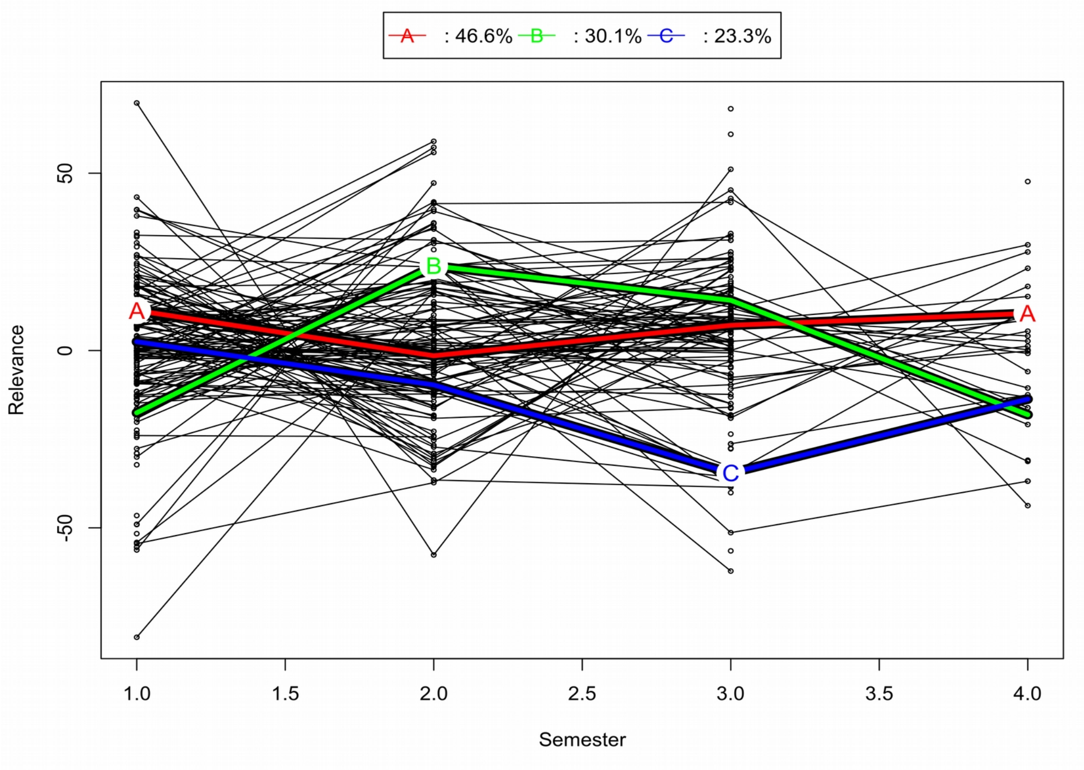

Figure 7.9: Longitudinal trajectory clustering for science student attitude ratings. Three general trends are visible in student attitudes towards relevance: A-neutral flat; B-weak-negative early-n-shaped; C-weak-negative late-u-shaped.

Students on trajectory B, start from a lower base-point than the other trajectories (M=-17.6, SD=21.2) before rising to a peak during semester 2 of year 7 (M=23.9, SD=18.7). Their rating scores then decline throughout year 8 reaching a new low at the end of year 8 (M=-18.1, SD=20.1). Trajectory C begins with students reporting ratings for science relevance that are neutral in comparison with their ratings for school as a whole (M=2.5, SD=18.3). These ratings then decline steadily to a low during semester 1 of year 8 (M=-34.5, SD=11.9) before improving noticeably by the end of year 8 (M=-13.7, SD=20.4).

Relationship between CAR and science SAR relevance ATs

Figure 7.10 shows the assignment of science relevance trajectories against the trajectories identified in the analysis of composite school relevance. Each cluster in this diagram is referred to using a two-letter tuple in keeping with the approach outlined for enjoyability. Considering male students only, it is worth noting the high plot densities in combinations [A,A] and [B,A]. For female students the unusual plot density in combination [D,A] and the high densities in combinations [A,A], [B,A], [A,C], [B,B] and [C,B] are worth further analysis.

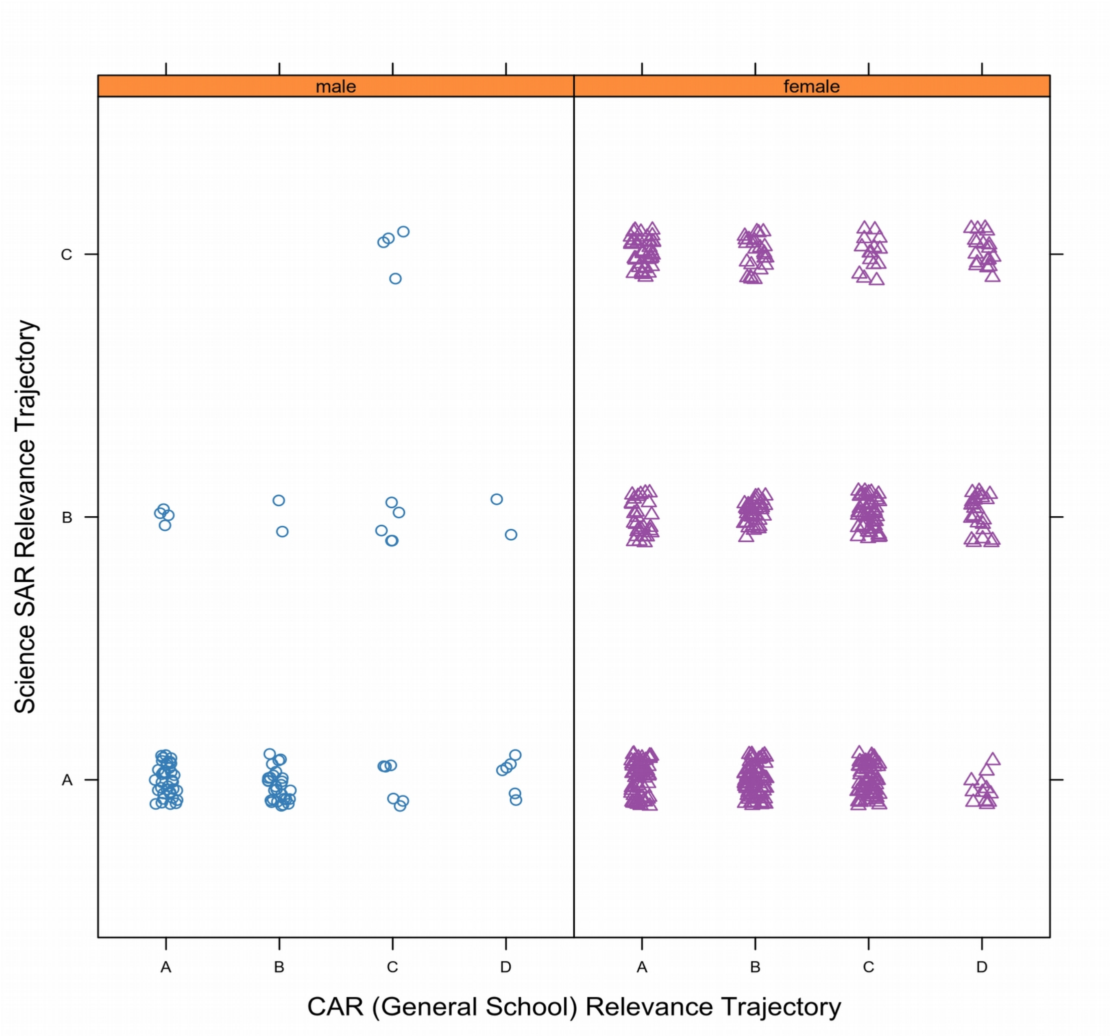

Figure 7.10: Plot of trajectories for composite attitude ratings of relevance versus science SAR relevance. The density of plotting points is indicative of the frequency of co-clustering.

The students, both male and female, in combination [A,A] report ratings for the relevance of science that are a mirror of their ratings towards school relevance in general (i.e. when their CAR rises, their SAR declines) although both the SAR and CAR remain neutral overall. In the first half of year 7 they report ratings for science that decline relative to their CAR relevance ratings which steadily rise. These trends reverse from the second half of year 7 onward. However, these students commented positively about their experiences in science, in particular around positive experiences of practical science. For example, "I learn quite a lot and do interesting experiments" $F_{[A,A]}$ or "Most lessons we get up and do an experiment, then analyse it" $F_{[A,A]}$. These comments suggest that although students found practical science experiences enjoyable they do not perceive them to be as relevant to their day-to-day lives compared to the relevance of other subjects. Similarly, female students in combination [B,B] also show a trend in their science relevance SAR that mirrors their CAR. The changes in the CAR and SAR for these students are more noticeable than for the students in combination [A,A] (ranging from weak-negative to weak-positive rather than remaining neutral) and suggest that their perceptions of the relevance of school subjects, particularly science, has a more marked influence on their formation of attitudes. It is also worth noting that while the students in combination [A,A] reported a u-shaped SAR trajectory—that is a decline followed by a rise—the students in combination [B,B] reported an n-shaped SAR trajectory.

The students in combination [B,A] report changing rating trends that are similar in shape for both their CAR and SAR, relevance although the magnitude of the changes in the SAR are less than the changes in the CAR. That is to say that as they report declining relevance for science in the first semester of year 7, their ratings overall also decline and suggests that science is a *normal* subject within their curriculum mix rather than something unique or special.

Female students in combination [A,C] report ratings of relevance towards science that are consistently lower than their composite attitude rating for relevance. During the first semester of year 7 their ratings towards science decline while their CAR increases slightly. However, from semester 2 year 7 onward, both their science SAR and CAR decline steadily; although their science rating for relevance recovers a little during semester 2 of year 8. This is indicative of students who have some difficulty in seeing the relevance in their school subjects including school science.

Female students in combination [C,A] show a trend in their science SAR for relevance that is relatively neutral in comparison with their CAR. Explanations offered by students suggest that they may have a focus on a science-based career. For example, “being a scientist would be really fun because you get to explore different things” $F_{[C,A]}$ or “I'd like to be a medical scientist” $F_{[C,A]}$ or “It may be a tough career being a female, but it would be interesting” $F_{[C,A]}$. In turn this targeted focus may allow them to continue to perceive the relevance of school science while their perceptions of the relevance of other academic aspects of school fluctuate.

Student explanations for changing their science relevance rating

A network graph linking the coded forms of the explanations offered by students in regards to their relevance ratings (Figure 11) indicates the significance that students place on interest, applications and uses for science in forming positive attitudes towards both the personal and career relevance of school science. Slightly surprisingly irrelevant was linked to only the code "boring" suggesting that students do not in general see school science as irrelevant per se, but that their perceptions of its relevance decline with exposure to boring learning experiences. Interestingly, experiences coded as "negative change" such as " I didn't do well in the exams" $F_{[A,C]}$, appear to impact a student's perceptions around the personal and career relevance of science, as well as its perceived irrelevance.

Figure 7.11: Network graph showing the links between coded students' explanations and the positive (career and personal relevance) and negative (irrelevant) attitudinal positions of relevance (blue circles).

The degree of linking of the coded explanations are indicated using colour; white indicates that a code is linked to only a single attitudinal position while orange indicates that the code is associated with more than one position.

It is also notable that the code "teacher" is not linked with relevance indicating that students' attitudes towards the different aspects of relevance appear to be not influenced directly by their interactions with their teacher. However, passionate—a student's desire to learn science for its own sake—and discovery—which relates to student experiences where they are able to learn more independently—are linked to personal relevance and, given the nature of a school science laboratory, it is fair to assume that this passion and freedom of discovery must be at least facilitated by the teacher. Finally, it is also clear from Figure 7.11, that the sub-domains of science are linked with career, but not personal, relevance. This suggests that students can see value in the different areas of school science and associate these with specific careers rather than combining all the areas of science under a single umbrella term.

Summary of main messages relating to students perceived relevance of school science

The results above highlight six main points about Year 7 and 8 students' perceptions of the relevance of their school science experiences. These are:

- Students hold attitudes towards the relevance of school science that are in general neutral when compared with attitudes towards the relevance of school subjects in general. Both male and female students show large variation at each measurement point with male students showing a slightly wider range of ratings on average.
- Students tend to follow one of three distinct attitude trajectories (Figure 7.9) related to the relevance of school science and the allocation of a particular student to one or another of these cannot be predicted reliably based only on student sex, school type or school location.
- The majority of students, both male and female, reported ATs for the relevance of science that associated closely with their composite ATs for the relevance of school more generally.
- Female students who reported an AT for science relevance that declined from early in Year 7 also tended to report an AT for composite relevance that declined from the middle of Year 7 onward.
- Many student explanations of their changed attitudes did not reflect the construct of relevance directly but instead related to experiences and enjoyableness in the classroom. Positive attitudes towards the relevance of science appeared to be linked with interest, applications of science and positive intentions towards science beyond school.
- Experiences that caused a general negative change of attitudes—as emerged from students' verbatim comments, for example poor assessment performance—were able to impact all facets of students' perceptions of the relevance of science.

Associations with Enrolment Intentions

We showed in Kennedy et al. (2018b) that student perceptions of the relevance and enjoyability of school science are strongly correlated with their intentions to continue the study of science beyond Year 10—the end of compulsory science education. From the analysis of the qualitative student explanations for their changed ratings of the enjoyability and relevance of school-science, six attitudinal constructs, with both positive and negative positions, were apparent. Four constructs; enrolment intentions, enjoyability, relevance, and self-concept were informed by and supported the previous research on attitude formation. The remaining two constructs; school-science, and achievement emerged from the qualitative analysis process outlined in this article. A network graph (Figure 7.12) shows a number of attitudinal positions (shown in blue in Figure 7.12 and representing positive and negative attitudes) relating to the three attitudinal constructs of interest in this article which are in turn linked from the codes (orange, yellow and white) of the qualitative analysis. The arrow on the link indicates that a code was used by students in explaining their attitude rating for that attitudinal position and points away from the position and towards the explanatory code. While ascribing causal relationships between variables is potentially problematic, the students in this study were specifically asked to explain their reasons for their changes in attitude rating. Therefore, we are able to use the information in their explanations to explore the nature of the influences acting on the formation of the attitudinal constructs of interest (enjoyability, relevance and enrolment intentions).

Table 7.6: Degrees of linking levels and number of paths for each of the attitudinal positions identified in the network map Figure 7.12

Attitudinal Construct →	**Enrolment Intentions**		**Relevance**			**Enjoyability**		**None**	
Path to → / **Path From↓**	**Positive Enrolment Intentions**	**Negative Enrolment Intentions**	**Personal Relevance**	**Career Relevance**	**Irrelevant**	**Enjoyable**	**Unenjoyable**	**Unlinked**	**Number of paths from theme**
Positive Enrolment Intentions	-	3	7	7	0	12	5	3	34
Negative Enrolment Intentions	-	-	1	3	2	3	9	9	21
Personal Relevance	-	-	-	6	1	6	2	1	23
Career Relevance	-	-	-	-	1	8	3	1	28
Irrelevant	-	-	-	-	-	0	2	0	6
Enjoyable	-	-	-	-	-	-	6	6	45
Unenjoyable	-	-	-	-	-	-	-	0	26

The degree of linking—the number of links associated with a particular code—of the coded explanations is indicated using colour and also by the size of the circular node containing the code. A path follows the links between two attitudinal positions, either directly or via a code, and indicates that the two positions are interrelated and codependent on the code. For example, the attitudinal positions enjoyable and unenjoyable are linked by six paths one of which passes through the code achievement. This indicates that a student's attitudinal position towards enjoyable is codependent on their attitudinal position to unenjoyable and that the student's experiences of achievement are able to mediate the nature of this codependency. By extension, the greater the number of paths associated with an attitudinal position, the more inter-dependent that attitudinal position can be considered to be. The number of paths between each pair of attitudinal positions is summarised in Table 7.6.

Similarly, the greater the degree of linking for a particular code the greater potential it has for influencing attitudinal positions. This is because there are a greater number of paths that pass though it and are therefore mediated by it. For example, "subject areas" has a degree of linking of five and appears on ten paths while "boring" has a degree of linking of three and appears only on three paths. It could be therefore inferred that the concept or ideas encoded in "subject areas" is likely to be more central to the formation of the linked attitudinal position than the ideas encoded in "boring" and thus offers greater potential for insight into understanding the formation of student attitudes.

As can be seen in Table 7.6 and Figure 7.12, students who reported having positive enrolment intentions (lower right hand corner of the network graph) indicate a large number of paths to the themes enjoyable, career relevance, personal relevance, and, to a lesser extent, unenjoyable. These paths run through two codes which each have a degree of linking of 5, three codes of degree 4 and eight codes of degree 3. This demonstrates that positive attitudes towards enrolment intentions, relevance of school science and enjoyability of science lessons are highly inter-dependent and are influenced by common underlying experiences, influences and/or perceptions. Conversely, the theme negative enrolment intentions is only linked strongly to the theme unenjoyable and to nine codes that are unique to negative enrolment intentions. The paths between these two themes run through three codes with degrees of linking of 5 one code of degree 4, one code of degree 3, three codes of degree 2 and one code of degree 0 (i.e. there is a direct relationship between these codes). The formation of negative attitudes towards enrolment intentions is therefore less dependent on other attitudinal positions and subject to more independent and direct influences.

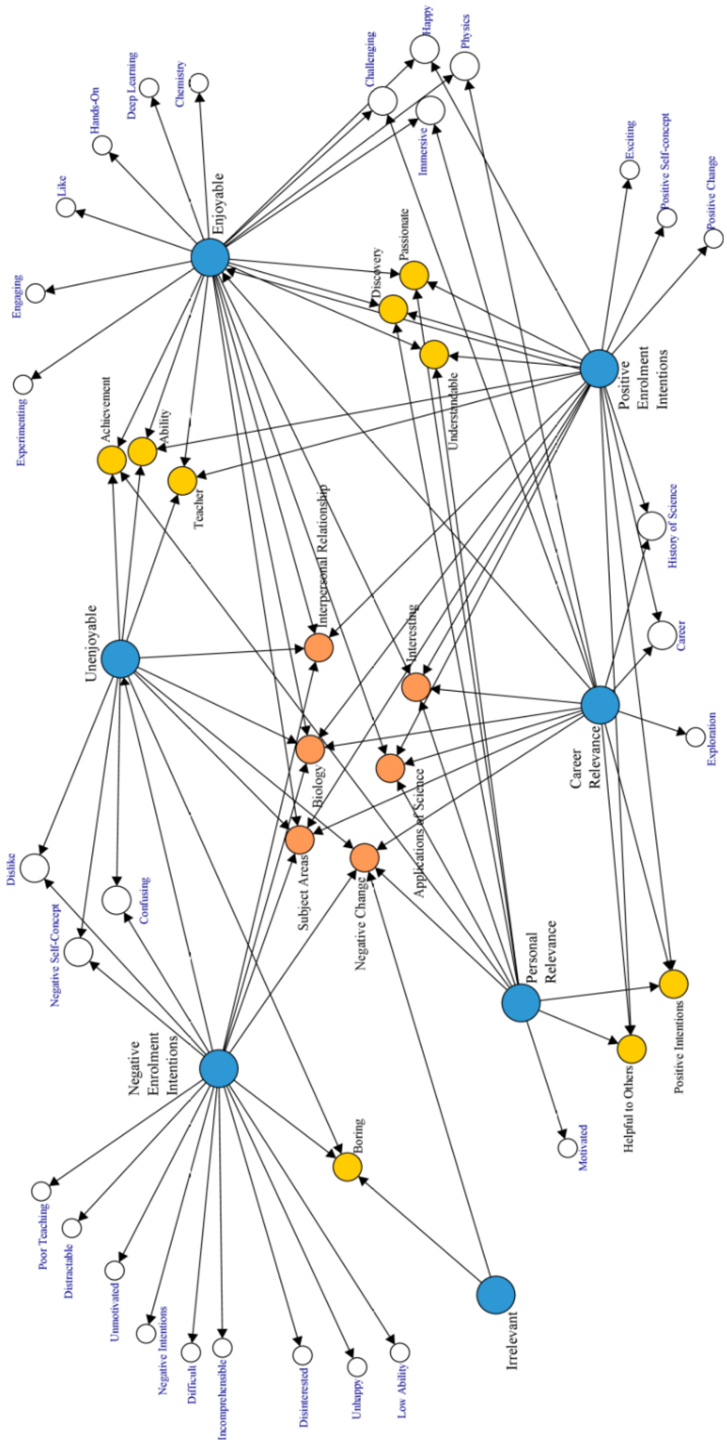

Figure 7.12: Network graph showing the links between coded students' explanations and positive and negative attitudinal positions for the attitudinal constructs of enjoyability, relevance and enrolment intentions (blue circles).

The degree of linking for coded explanations are indicated using colour: white indicates that the code is linked to 1 or 2 positions; yellow indicates that the code links to 3 positions; and orange indicates that the code links to 4 or more positions. The arrows on the links point away from the attitudinal position and towards the coded explanation that is used in forming that position.

Influences on negative science enrolment intentions

The interactions of codes and paths with negative enrolment intentions as shown in Figure 7.12 and Table 7.6 indicate that students' intentions not to enrol in post compulsory science can be ascribed to one of five categories. Firstly, the large number (nine) of unique codes connecting to negative enrolment intentions reflects a number of potential influences on students' intentions not to study science beyond year 10 that are not incorporated into any other themes investigated in this analysis. These tend to be expressed negatively and relate to personal perceptions of difficulty or negative affective influences. Secondly, there are a number of weakly interacting codes that relate to a student's negative experience of school science (boring (linking level 3), dislike (2), confusing (2), negative self-concept (2)). Thirdly, the nature of the sub-domains of science (as indicated by the codes subject areas (5) and biology (5)) interacts strongly with a both a student's unenjoyable perception of science and their negative intentions to continue to study the subject. Note that this could be equally interpreted as too much or too little exposure to a particular sub-domain. Fourthly, student experiences of school as a whole that result in an overall negative change in outlook (negative change (5)), link strongly with the formation of negative enrolment intentions in science and finding science unenjoyable. Finally, the interpersonal relationship with the teacher (linking level 4) indicates that for some students a negative relationship with a teacher can result in the formation of a negative attitudinal position towards enjoyability and negative enrolment intentions.

Influences on positive science enrolment intentions.

The links between positive enrolment intentions in post-compulsory science and the other attitude themes shown in Figure 7.12 and Table 7.6 are more strongly intertwined. Positive enrolment intentions are linked with enjoyableness through twelve paths and with both career and personal relevance through seven paths each. The paths between these four themes can be described using five broad descriptors. Firstly the nature of the sub-domains of science (indicated by subject areas and biology each with a linking level 5) is a strongly interacting set of codes between all four of the themes. Secondly, the potential uses of science (indicated by applications of science (4) and helpful to others (3)) is a moderately interacting group of codes that links both aspects of relevance to positive enrolment intentions. Thirdly, relationships with the teacher (indicated by interpersonal relationships (4) and teacher (3)) is a moderately interacting group of codes that links enjoyability and positive enrolment intentions independently of relevance. Fourthly, lesson engagement (indicated by Interesting (4), passionate (3), discovery (3) and enjoyable (3)) forms moderate three-way links between personal relevance, enjoyability and positive enrolment intentions. Finally, perceptions of the student's own ability within their cohort (indicated by achievement (3), ability (3) and understandable (3)) forms moderate links between enjoyableness and positive enrolment intentions.

Discussion and Conclusions

The finding that school type (co-educational vs single sex), school location or student sex, had no statistically significant influence on the allocation of the students in this study to any particular AT for either enjoyability or relevance is interesting. This shows that for the students in this study, the AT for enjoyability or relevance followed by any particular student can not be predicted on the basis of student sex, school location or school type (single sex vs co-educational) alone. Many researchers have argued for (e.g., Dee, 2006; Robinson & Smithers, 1999; Stables, 1990) and against (e.g., Halpern et al., 2011; Harker, 2000; Robinson & Smithers, 1999) single sex education, either in its full form or in the form of single sex classes within co-educational schools. However, this finding suggests that, for the enjoyablity and relevance of science at least, this debate is a moot point for both sides of the argument.

Additionally, Figure 7.12 and Table 7.6 show that some of the identified codes seem to have wider influence on student attitudes towards school science than others. In particular, the nature of the sub-domains of science and the nature of interpersonal relationships with the teacher are two themes of special importance, as they strongly interact with the formation of both positive and negative enrolment intentions by students. The number of paths between enjoyability and personal and career relevance, enjoyability and positive enrolment intentions, and personal and career relevance and positive enrolment intentions towards science, while not definitively describing causal relationships, does emphasise the level of interrelatedness of these student attitudes towards science. This suggests that interventions designed to have a positive impact on one or more of these attitudes could indirectly influence multiple attitudes, and conversely, might deliberately and explicitly target all four of these attitudes at the same time.

It is also evident from the number of varying ATs of differing shapes assigned to students for both enjoyability and relevance, that a wide range of influences are able to affect the formation and refinement of students' attitudes. However, (and while trying to avoid over-generalising) Figure 7.4 shows that nearly 70% (ATs A and B) of the Year 7 students in this study were reporting that their attitudinal ratings for the enjoyability of school science were in gentle decline by early Year 8 (semester 3). This contrasts with our findings in our earlier study (Kennedy et al., 2018b, p. 15) which showed that overall both male and female students reported greater enjoyability in semester 2 of year 7 than in semester 1. This indicates that the second half of year 7 or the early half of year 8 coincides with a turning point experience or event for the students in this study that influences the reported enjoyability ratings for science. Similarly, Figure 7.9 indicates that around 53% (ATs B and C) of these same students were reporting declining attitudes in respect of the relevance of school science by the end of year 7 or early year 8. These declining attitudes towards enjoyability and relevance are of particular interest when considered as part of the complex networks of influences shown in Figures 7.6, 7.11 and 7.12.

Through these network diagrams it is apparent that there are four key influences on enjoyability, relevance and intentions to enrol in post-compulsory science. Firstly, negative changes in attitude (the code negative changes) towards school subjects in general interact with all three attitudinal positions or the relevance construct as well as with the unenjoyable attitudinal position of the enjoyability construct (Figure 7.12). This suggests that the attitude of students in this study towards the relevance of school science is likely tested against a much wider benchmark than school science alone and formed in conjunction with other subjects. This is in accord with previous suggestions by an number of researchers (e.g., Lyons & Quinn, 2015; Sheldrake, Mujtaba, & Reiss, 2017) but is here demonstrated empirically, and is an area for future research that is likely to yield further fruitful insights. This observation also suggests that placing a stronger pedagogical emphasis on the personal relevance of school science and its cross-curricula links could provide good opportunities for students to see reasons to later enrol in post-compulsory science.

Secondly, the individual sub-domains within science—namely biology, chemistry, physics etc.—appear strongly linked with both of the attitudinal positions of the enjoyability construct (enjoyable and unenjoyable), with the specific careers attitudinal position of the relevance construct, and with both attitudinal positions (positive and negative) of the enrolment intentions construct. All students who contributed to this study followed an integrated science course and curriculum. Yet even so, students' comments identified some of the differences between the various sub-domains of science. For example, comments relating to the enjoyability of biology or physics suggest that students in the early stages of high-school are recognising and responding to the differences between subject areas. These differences might relate to variations in the discipline-specific knowledge, ways of thinking, associated classroom practices or pedagogical approaches adopted across each of these discipline areas. It is interesting to note, however, that the attitudinal position personal relevance is not linked directly to these codes. Yet, because personal relevance forms a large number of paths to the attitudinal positions enjoyable and career relevance, the science sub-domains might indirectly affect students' attitudes of personal relevance. The varying attitudes of enjoyability and career relevance in relation to science sub-domains may also account for some of the seasonality seen in Figure 7.7, and to a lesser extent in Figure 7.2. The position and prominence of the sub-domain codes in the network diagram suggests that students are discerning whether sub-domain information and experiences are relevant for a specific (not necessarily their own) career path or not, while at the same time forming an opinion about the enjoyability of that area of science. This may also suggest that students who do not find school science enjoyable are unlikely to see themselves on a science-related career path in the future.

Thirdly, and related to subject area, the codes applications of science, interesting, helpful to others, passionate, and discovery are not linked to the attitudinal positions of negative enrolment intentions, irrelevant or unenjoyable. This implies that while the absence of a real-life application for the science learned in school is not necessarily detrimental to the attitudes of the students in this sample, the existence of a suitable and engaging application can only serve to build more positive student attitudes towards enjoyability, relevance, and enrolment intentions. However, when students are disinterested, unmotivated and distractable, it is their intentions towards future enrolment that are directly impacted (as indicated by the linking level of these codes (1) with the attitudinal position negative enrolment intentions).

Finally, the formation of interpersonal relationships between students and teachers has been shown to influence both positive and negative enrolment intentions as well as both attitudinal positions of the enjoyability construct. It is therefore a key requirement of forming positive attitudes towards the enjoyability of science and future enrolment intentions that positive relationships between student and teacher are formed and maintained. This is in keeping with other research (e.g., Attard, 2015; Hattie, 2003, 2008;

Ornstein, 2006) that emphasises the significant proportion of variance in student attitudes that is a result of a teacher's actions and behaviours.

Considering all of these attitudinal links, paths and trajectories, it can be concluded that students' intentions to enrol in science are being facilitated (or not) by year 7 and year 8 teachers. It is important that schools recognise the significance of what happens in years 7 and 8, and that teachers who are entrusted to actively engage the younger students in high-schools are passionate and knowledgeable about both their specialist subject areas and teaching in general, can build strong interpersonal relationships with students, are able to draw out the applications of science for students, can nurture a personal relevance for the content they teach to their students and can promote a learning environment that is challenging, interesting and based around discovery. In their daily work, teachers are directly and indirectly shaping their students' attitudes and intentions to enrol in post-compulsory science. Hence it is important for our students and our society that students are not turned away from science at this point in school, and that the door is held open for them to follow what they enjoy and see as relevant, and pursue their aspirations in subsequent endeavours. In this way, we might retain and nurture the aspirations of those students disposed towards learning more about or working in science.

7.3 Statement of authors' contribution

We, the PhD candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in this thesis and they have accepted the candidate's contribution as indicated in the Statement of Originality.

	Author's Name	% of contribution
Candidate	JohnPaul Kennedy	80
Other Authors	Dr Frances Quinn	10
	Associate Professor Terry Lyons	10

[redacted]

JohnPaul Kennedy
(Candidate)

25th September 2018

[redacted]

Dr Frances Quinn
(Principal Supervisor)

25th September 2018

7.4 Statement of originality

We, the PhD candidate and the candidate's Principal Supervisor, certify that the following text, figures and diagrams are the candidate's original work.

Type of Work	Page Number/s
Figure 7.1	185
Figure 7.2	186
Figure 7.3	188
Figure 7.4	190
Figure 7.5	193
Figure 7.6	195
Figure 7.7	196
Figure 7.8	198
Figure 7.9	199
Figure 7.10	201
Figure 7.11	205

[redacted]

JohnPaul Kennedy
(Candidate)

25th September 2018

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Dr Frances Quinn
(Principal Supervisor)

25th September 2018

Chapter 8: General Findings and Discussion

Chapters 3 to 7 of this thesis have detailed five individual research articles that have together addressed the two primary research themes outlined in Chapter 1. These two themes were broken down into eight research questions (Chapter 2) which were each focused on more tightly in subsequent chapters. In this chapter, I first synthesise the findings of the previous chapters against each of these research questions and then against the overall research themes. I then draw these findings together to identify the limitations of this research and the implications for educational practice, theory and future research.

8.1 Synthesis of Findings

RQ1: To what extent are the reported declines in participation in high-school science and mathematics courses across Australia continuing into the second decade of the twenty-first century?

This thesis began with the language of crisis in response to the significant, contradictory and confusing media coverage (e.g., Goodrum, Druhan, & Abbs, 2011; Smith, 2011) surrounding the apparent declines in participation for science and mathematics courses in Australian high-schools that was frequently reported around 2010. By expanding on and updating previous rigorous work in science and mathematics enrolments (Ainley, Kos, & Nicholas, 2008); which similarly extended prior research (Dekkers & de Laeter, 2001; Dekkers, De Laeter, & Malone, 1986; Dekkers & Malone, 2000), I was able to show that the numbers of students enrolling in science and mathematics courses were in many cases stable and not actually in decline (Figure 3.3). However, once the general growth of Year 12 students was taken into consideration, I established that participation rates for almost all science and mathematics courses were in fact continuing to slowly decline in real terms (Figure 3.2), although at a rate of decline less than in the years prior to 2002. The exceptions to these general trends were entry mathematics, which was demonstrating rapid growth, and biology and chemistry which were both relatively stable in terms of participation rates.

RQ2 What is the nature of the participation trends in the other STEM fields of technology and engineering?

Chapter 4 examined patterns of student participation in the technologies and engineering domains of Australian high schools. Comparing Figure 3.2 with Figure 4.2 shows that the changes in participation rates within these subject areas are very different in appearance to those for science and mathematics. The trends show that participation rates in the technology and engineering domains in general are low in comparison to science and mathematics, but have been gradually rising in general terms.

The notable exception to this rising trend is digital technologies which rose strongly throughout the 1990s before plummeting in the early 2000s. As I noted in chapter 4, this uniquely shaped trend is indicative of an external factor that promoted digital technologies prior to 2000 but then suddenly lost influence thereafter. The hype associated with the growth of the Internet throughout the 1990s, and the Dot-Com bubble (and subsequent bust) might conceivably have played a role in these trends; however, the cause of the sudden change in participation cannot be determined from enrolment patterns alone. The turning point also coincides with the renewal of course syllabi in many states and territories, the recognition of VET as part of Year 12 qualifications, and also the broadening of the curriculum as a whole to provide wider choice to students which may also have had an effect on digital technologies. For example, it is not inconceivable that the observed declines in participation could be due to students enrolling on one of the many new courses in place of digital technologies which may have become passé.

RQ3 To what extent are the trends in participation similar and different between the various STEM fields and in what ways are they linked with broader curriculum offerings?

Around 2006, the student participation rates for chemistry and biology appeared to begin to stabilise and stop the declines of the previous decade (Figure 3.2). However, there has yet to be a reversal of the earlier declines. The year 2000 saw the introduction of many new courses across Australian secondary schools, resulting in significant curriculum broadening. This created an increased range of subjects from which students could choose. In addition to this it has been suggested that systemic changes—such as the transition away from prerequisite courses by universities and the reduction in the minimum number of required subjects in some states and territories—may have combined to encourage students to select year 12 courses primarily on the basis of immediate interest or maximising their tertiary admissions rank, rather than as a foundation for longer term future needs. The shape of the participation trends seen for the two most popular science courses of biology and chemistry may therefore be a consequence of the popularity of the new subjects rather than a rejection of the old.

In Figure 3.2, a symmetry is apparent between the participation rate trends of entry and intermediate mathematics. I suggested that the growth in entry mathematics was not due to an increased proportion of Year 12 students studying mathematics, but was a consequence of students selecting a non-calculus course in preference to a calculus-based course. Subsequent research in this area (Hine, 2018) has supported this hypothesis and found that a number of high achieving students choose to study the entry level mathematics course because success at this level can assist in maximising their Australian Tertiary Entrance Rank while not deselecting themselves for tertiary study in areas such as engineering. Hine suggested that this was a direct consequence of the removal of prerequisite courses for university entry. Other researchers (Brown, 2009; Nicholas, Poladian, Mack, & Wilson, 2015) have shown that students who enrol in intermediate and advanced mathematics courses at high-school are likely to be more successful in first year university science and mathematics programmes than students who enrolled in entry level mathematics.

The combined findings from chapter 3 and 4, revealed some interesting correlations between participation rates in various STEM course areas. There were strong, statistically significant, positive correlations between participation rates in each of physics, mathematics and advanced mathematics with digital Technologies post-2000 (Figure 4.6). The data suggests that students started to transition away from traditional science and mathematics course areas during the 1990s and towards the newer digital technologies. However, when the declines in digital technologies began, students transitioned into other new courses across the curriculum rather than return to the traditional science subjects.

Figure 4.6 also showed that participation rates in physics, mathematics and advanced mathematics correlated strongly and negatively with engineering and that physics and advanced mathematics showed strong positive correlations with engineering in their residuals. This finding suggests that at least some students may have opted to study engineering when offered in the final two years of high-school in place of physics or advanced mathematics.

Finally, Figure 3.2 showed that trends in physics participation rates very closely followed those seen for advanced mathematics. I argued that this common pattern was suggestive of the existence of a common causation; that is a common attitudinal position may underlie students' enrolment intentions towards physics and advanced mathematics. However, recent changes in the physics and mathematics curricula at the national and state levels have resulted in the degree of interdependence for school science and mathematics courses increasing (Georgiou & Crook, 2018). It is therefore likely that the participation trends for these two course areas will remain coupled into the short to mid-term future.

RQ4 To what extent does student sex influence the trends in participation across the STEM fields?

In both Chapter 3 and Chapter 4, I showed that the participation rates of students in the sciences, in mathematics and in the technologies was highly linked with the student's sex. Figure 3.4 presents the sex ratios for science and mathematics courses while Figure 4.4 shows the same information for technologies courses. These graphs showed that some subjects have resolutely remained biased in terms of the sex-balance of the students enrolling on the course over time, while a few have adjusted slowly towards parity. The subject areas where male students dominate the classroom include design technology, engineering, physics, intermediate mathematics and advanced mathematics. Female students predominate in biology and food technology. Earth sciences, food and fibre technologies and, to a lesser extent, chemistry have slowly shifted from being male-dominated classroom environments to being much more evenly balanced, while entry mathematics has slightly shifted from being female biased to parity. Uniquely in the subjects studied, digital technologies has steadily drifted from parity towards being very heavily dominated by male students.

The possible reasons for these apparent sex-biases are many and complex. There has been intensive research in this field exploring the reasons for females leaking from the so-called STEM "pipeline' (Clark Blickenstaff, 2005) which has highlighted a lack of positive female stereotypes, differing career aspirations and desires, and beliefs about a student's lack of ability compared to their peers—among other explanations—as key factors in need of redress. My analysis of attitudinal data (Chapter 6) concluded that female Year 7 students believe that they are less able in science, find technologies less personally useful, and mathematics less relevant than their male peers. However, I also concluded that male and female Year 7 students were more alike than they are different in terms of their attitudinal positions towards STEM subjects.

RQ5 To what extent do general patterns in school enrolments such as overall retention, impact on the participation rates in the STEM fields?

The National Partnership Agreement on Youth Attainment and Transitions (Council of Australian Governments (COAG), 2009 s 20) required that all Australian youth remain in full-time education or training until at least the age of 17 years. This might have been expected to increase the retention rate of students from Year 10 to 12 from 2012 onward—that is two academic years after the agreement came in to effect (Figure 3.1) as the students who would have traditionally left school at Year 10 became compelled to remain within schools. However, I observed neither an increase in retention rates around that time (see also Figure 4.1) nor any significant alterations to the rate of change of the participation-rate trends in any STEM course analysed (Figure 3.2 and Figure 4.2). This result may relate to post-compulsory enrolments in TAFE or other educational pathways, which were beyond the scope of this thesis to investigate.

Figure 4.6 analysed the correlations between retention rate and five STEM areas. For all five courses presented—and also for biology, chemistry and entry mathematics which are not presented graphically—no relationship between retention rate and participation rate was found. I therefore conclude that any changes in the composition of the Year 12 cohort is unlikely to have 'diluted' the retention rates in the STEM areas.

RQ6 Can an instrument be developed to quickly measure students' self-reported attitudes towards their school subjects over time?

The assumption that declining enrolments in post-compulsory science and mathematics are due in part to declines in attitudes to these subjects in early high-school is implicit in many initiatives aimed at improving both attitudes and enrolments. The underlying premise is that if it can be understood what factors hinder a student from forming a positive outlook towards the STEM areas, then suitable interventions may be designed and implemented so as to directly address student attitudes and thence declining participation. However, while many tools exist that can measure an aspect of a student's attitude towards an area of the STEM courses (Table 5.1), no tool was available that could measure changes in student attitudes longitudinally and across the full breadth of the curriculum.

In Chapter 5, I detailed the development of an instrument to address this identified need. The thorough statistical treatment of the development process yielded an instrument that appeared to be both valid and reliable while also being time efficient and flexible to use. The analysis showed that it is possible to reliably and validly assess student attitudes towards school science using an instrument template consisting of just ten, digitally facilitated, visual analogue, single-item measures. Furthermore, this instrument was able to yield multi-dimensional profile data relating to seven aspects of a student's attitudes towards school and record changes in these attitudes over time.

In Chapter 6 and Chapter 7, this instrument was used to obtain attitudinal data from over 350 student participants from across New South Wales which was subsequently analysed using subject and composite attitude profiles (SAPs and CAPs). The analyses in these two chapters demonstrate the power and flexibility of such an approach to data collection. It is also interesting to note that Toma and Meneses Villagrá (2018) were able to use a derivative of this instrument in their study and that the validity and effectiveness of the tool and data were unaffected by the translation into Spanish or the localisation of the instrument to primary education in Castile.

RQ7 To what extent do student attitudes towards STEM change and develop throughout the early years of high-school?

Chapter 6 examined attitudinal profiles for science, mathematics and design technology for Year 7 and how these changed over the first year of high-school. I showed that in general, students considered science to be more difficult and less enjoyable than their other school subjects at the beginning of Year 7 (Table 6.3). Yet, they acknowledged that school science was useful for their potential future careers and reported a strong intention to continue with the study of a science course after Year 10 compared to their other school subjects. On average, students' attitudes did not vary significantly in many respects between semesters 1 and 2. However both male and female students reported a rise in their attitude ratings for enjoyability and specific career usefulness over this first year of high-school.

Chapter 7 developed these ideas further by considering the attitudinal trends of students throughout Years 7 and 8 in regards to the enjoyability and relevance of school science. I was able to identify four distinct attitude trajectories that described how students attitudes towards the enjoyability of science change over the first two years of high school and three distinct trajectories for attitudes towards the relevance of science. In general, I found no clear correlation between male students' ratings of enjoyability of school science and their ratings of the enjoyability of school subjects in general. I also found that female students who reported rising attitudes towards the enjoyability of school subjects in general tended to report an initial rise in attitude rating for school science which then fell away slowly over time. The majority of students', both male and female, reported attitude trajectories for the relevance of science that associated closely with their attitude trajectories for the relevance of the academic aspects of school more generally.

Reported attitudes towards mathematics were significantly less positive than the composite school ratings in many regards (Table 6.5) although student attitudes towards mathematics increased over year 7 in respect of its usefulness for mathematics-specific careers. Female students in particular reported that they find mathematics lessons harder, less enjoyable and far less personally relevant than their other school subjects. Even so, students were able to identify mathematics as a set of important skills that are essential for life after school and indicated a strong intention to continue to study mathematics into Year 11 and 12.

Compared to mathematics and science, students indicated extremely positive attitudes towards design technologies at the outset of Year 7 (Table 6.7). Students rated enjoyability and usefulness particularly favourably in comparison to their school subjects in general. However, by semester 2, all attitude measures towards design technologies had become much lower for both male and female students.

It is clear from the analyses presented in Chapter 6 and Chapter 7, that the different STEM areas face different challenges in terms of maintaining and improving student attitudes towards them. It is therefore important that a one size fits all approach is not applied to improve attitudes towards the STEM areas of education. Rather, these analyses suggest that locally meaningful, carefully targeted, subject specific interventions will be required to improve attitudes towards science, mathematics and design technology and then maintain those attitudes at this new level.

RQ8 What factors appear to affect students' attitudes and enrolment intentions towards further study in STEM fields?

In Chapter 6, I showed that there were a number of differences between male and female students in regards to their attitudes towards the STEM subjects. In general, females found the sciences and mathematics less relevant, less enjoyable and more difficult than their male peers. However, when student attitudes towards enjoyability and relevance for science were examined more closely and over a longer period (Chapter 7) I found that neither school type (co-educational vs single sex) nor school location nor student sex had any statistically significant effect on the allocation of students to particular attitudinal trajectories. That is, for the students who participated in this study, their attitudinal trajectories for enjoyability or relevance could not be predicted from the bases of student sex, school location or school type alone.

The findings of Chapter 6 and Chapter 7 also suggest that while the range of attitudes held by students towards the STEM areas is both wide and very varied, the subject attitude profiles held by many of the student, both male and female, for the science, mathematics and design technologies (Figure 6.4, Figure 6.5 and Figure 6.6) are still very alike in many ways. In particular, the students in this study tended to experience early secondary school with almost identical composite attitude ratings for enjoyability, usefulness, relevance and difficulty, yet these then diverged rapidly over time in some of the STEM areas.

Most of the changes in attitudes described in Chapter 6 showed small effect sizes with respect to student sex and the passage of time from semester one to two, a finding consistent with further analyses in Chapter 7. However, Chapter 6 identified three attitudinal changes in particular that demonstrated a moderate effect size with regards to student intentions to enrol in further study in STEM subjects. These included students' declining perceptions of the relevance of their STEM subjects over time, and students' ratings of the personal usefulness of technologies which also declines with respect to time. Thirdly, the trends shown for enjoyability indicate that male and female students respond differently in regards to the STEM areas based on their perceptions of the enjoyability of their lessons.

The network diagram analysis of Chapter 7 indicates that there are four influences among many that are key to understanding the links between students' attitudes towards enjoyability, relevance and intentions to enrol in post-compulsory science. Firstly, negative changes in attitude towards school subjects in general interact with all three attitudinal positions for relevance—personal relevance, career relevance, and perceptions of irrelevance. Secondly, students' explanations related to the individual sub-domains of science appear strongly linked with their attitudes of enjoyability, unenjoyability, relevance for specific careers for science, and with both their positive and negative enrolment intentions. Thirdly, the concepts of applications of science, interest in science, science as helpful to others, and discovery are not linked to the attitudinal positions of negative enrolment intentions, irrelevance or unenjoyablity of school science. Finally, the formation of interpersonal relationships between students and teachers influenced both positive and negative science-related enrolment intentions as well as both enjoyability and unenjoyability of school science.

8.2 Limitations of Findings

The approaches to the data collection and analyses presented in this thesis have a number of limitations that must be acknowledged in drawing together these conclusions. Firstly, in regards to sample size and composition. Although many schools were approached across New South Wales through a variety of avenues in an attempt to obtain a student sample population that was as representative of the wider community as possible, some opportunistic sampling occurred and the final sample was not as representative nor as large as was desired. In addition, as the recruitment of students within those schools was also subject to opportunistic random sampling, the stratification that was present within the sample had the potential to bias the findings of the analyses. As a result, it is important to acknowledge that the previous discussions and the subsequent implications must be interpreted within these caveats relating to the sample.

Secondly, and related to the sample size is the effect of attrition. As with any longitudinal study, attrition of participants plays a major role in determining the representative nature of the sample. In this study, I began with over 400 participants but was only able to track 366 of them between two reporting times. By the end of Year 8, this sample size had fallen to 176. While this attrition rate is low by the standards of longitudinal studies, it was sufficient to require some modification to the proposed data analysis procedures. When combined with missing data, compromises had to be accepted from a data analysis perspective. I had planned to collect and report student data on a termly basis; however, out of necessity the analysis intervals were extended to semesters resulting in further data having to be discarded.

Finally, the number of students who felt comfortable enough and / or had the desire to contribute a qualitative explanation to the project was relatively low, with around 70 students contributing short qualitative data of some form to the study. It is important to acknowledge that while this leads to a range of relatively short verbatim comments, the concepts and ideas contained within those comments were appropriate for the network analyses presented in Chapter 7 to be carried out.

8.3 Implications for Practice

There are a number of implications for classroom practice that emerge from this thesis. Firstly, Chapter 7 showed the importance of teachers providing their students with a real-life application for the content that they are learning in the classroom. While the perceived absence of such an application was not necessarily detrimental to the attitudes of the students in this sample, the existence of a suitable and engaging application can only serve to build more positive student attitudes towards enjoyability, relevance, and enrolment intentions as seen through the network diagram Figure 7.11. Similarly, when students are disinterested, unmotivated or distractable, they expressed less intention to continue with further study in science.

Secondly, as noted in Chapter 7, a number of researchers (e.g., Dee, 2006; P. Robinson & Smithers, 1999; W. P. Robinson & Gillibrand, 2004; Stables, 1990) have promoted single sex education as either the saviour or enemy of increasing enrolments by female students in STEM areas. However, this research has shown that the sex balance of the classroom had no significant effect on students' attitude trajectories at least in regards to science. This may also explain why the sex-balance of many of the STEM courses (Figure 3.4 and Figure 4.4) has remained so stable over time.

Thirdly, Chapter 7 also noted the strong influence of interpersonal relationships between teacher and student in mediating both positive and negative enrolment intentions towards science. It is therefore key that positive relationships between student and teacher are formed and maintained. This is in keeping with other research (e.g., Attard, 2015; Hattie, 2003, 2008; Ornstein, 2006) that emphasises the significant proportion of variance in student attitudes that is a result of a teacher's actions and behaviours.

Finally, based on the evidence of the correlation matrices presented in Chapter 6 the attitudes that appear to have the strongest association with a student's intentions to continue study in the STEM fields are relevance and personal usefulness, while enjoyability and self-efficacy are also relatively strongly linked. The analysis presented in Chapter 7 concurs with this finding which is in agreement with other research (Ardies et al., 2015; Lyons & Quinn, 2010; Sheldrake, Mujtaba, & Reiss, 2017) and suggests that enhancing and leveraging from these attitudes may go some way to increased student intentions to enrol in post compulsory STEM fields.

All students who contributed to this study followed an integrated science course and curriculum. Yet even so, students' comments identified some of the differences between the various sub domains of science. These differences might relate to variations in the discipline-specific knowledge, ways of thinking, associated classroom practices or pedagogical approaches adopted across each of these discipline areas. However, the position and prominence of subject area in the network diagram (Figure 7.11) suggests that students are discerning whether sub-domain information and experiences are relevant for a specific (not necessarily their own) career path or not. This gives teachers the opportunity to engage students with the applications and uses of school science and allows the opportunity for students to expand and inform their thinking about specific scientific sub-disciplines.

8.4 Implications for Theory

This thesis adopted a theoretical definition of an attitude as being "the feelings that a person has about an object, based on their beliefs about that object" (Kind, Jones, & Barmby, 2007, p. 873). The "object" for the purposes of this definition was considered to be the individual school subjects studied by a student. The various attitude profiles constructed in Chapters 5, 6 and 7 emphasise that attitudes cannot be reduced to a singular measure. Instead, a student's attitude profile identifies the relative priorities of the different attitudinal constructs and emphasises their interconnectedness. These interconnected attitudinal constructs operate differentially on a student's intentions towards later enrolling in that subject.

Furthermore, this thesis has shown that students' attitudes towards the STEM subjects can change significantly over the course of a single year and beyond. In addition, this thesis has identified visible differences in students' subject attitude profiles between each of the individual STEM disciplines. Hence it is reasonable to suggest that the circumstances influencing the formation of positive attitudes towards science, mathematics and design technology are likely quite different from each other and each area would therefore require its own highly tailored and targeted approach to addressing attitudes.

In this thesis I have also demonstrated that it is possible to reliably and validly assess student attitudes towards school science using a simple and efficient digital instrument. Furthermore, the analysis shows that the use of these single-items can be as reliable as multiple-item scales in this context, particularly when combined with Visual Analogue Scales. If this approach is transferable to other research contexts then it offers an alternative approach to the collection of quantitative research data that addresses limitations such as attrition and time constraints that are associated with long surveys containing multiple-item scales.

8.5 Implications for Further Research

While this study has answered the research questions I set out to investigate, it has also identified a few areas where further research would be valuable. Chapter 6 identified that students' attitudes of relevance towards STEM subjects generally declined over time. As the passage of time alone cannot explain the changes it is important to consider which of the experiences Year 7 students gain over this year, that are likely to be similar between schools across NSW, might reasonably be associated with declining perceived relevance.

This thesis adopted the de-facto curriculum model of separate S, T, E and M subjects that is still common in Australian schools. I have shown that these areas appear to remain as fairly distinct discipline entities from a student perspective with distinct attitudinal characteristics. It is therefore worth investigating the extent to which integrated STEM initiatives alone might lead to the development of the espoused positive attitudes in school students to STEM in general when compared with the status quo model.

This thesis has also indicated that attitudes towards science are already declining for some students during the first year of high-school. This in some respects contradicts the not infrequent claim in the literature that attitudes and intentions towards STEM are formed in Primary school (e.g., Jenkins & Nelson, 2005; Murphy & Beggs, 2003; Turner & Ireson, 2010). Clearly for the students in this study, early high-school experiences are still influencing their attitudes to science, mathematics and technology. A larger study with data collected more frequently may reveal a turning point in attitudes within Year 7, though it should also be considered that sub-optimal attitudes towards the STEM disciplines may already be substantially formed before students reach the high-school gates. In this respect, it would be helpful to re-validate and repeat this study within the context of upper-primary schools while also tracking students across the primary-secondary school divide. The data from such a study would likely be invaluable in informing the most appropriate timing for the plethora of opportunities—such as competitions, outreach and extension programmes—available to schools in the STEM areas.

Chapter 9: Epilogue – A note to other doctoral researchers.

When I began this research journey nearly eight years ago, I had the naïve idea that because I was a science teacher working directly with students in my own classroom I might be in a unique position to be able to engage in a research process that could potentially have real, visible effects for me and my students at the 'chalk-face'. However, having now completed this journey I have come to fully realise how powerful engaging in the research process can be for its own sake.

Like most researchers, I started with the aim to 'fix' something that appeared to be broken; I approached the world like an engineer approaches the world. Yet, this research, through its twists and turns, in its high points and low points has required me to utilise skills and knowledge from my background as a physicist, from my vocation as an educator and from my experience as a learner in order to distil something new that is greater than the sum of its parts. It is this change of perspective that has been the most significant aspect of learning that I can take away from the process of completing doctoral research. It has been said that there are three noble professions; Doctors, Teachers and Priests. Those people who bring people into the world, those people who help you to learn about the world, and those people who help you out of this world. It is now my belief that to this list should be added Philosophers; those people who research the world and discover new things about it.

I embarked on this research with the egomaniacal objective of fixing a quandary that, in hindsight, appears to have been more of a katzenjammer than a crisis. However, I have instead developed new techniques, new approaches and new insights that can be truly said to be 'new'. I have found that the research process, similar to a fractal image like the cover of this thesis, is capable of revealing an almost infinite number of levels of complexity the more the researcher is able to penetrate into the questions that emerge from the research itself; knowledge begets knowledge. I have also come to realise that the system of processes and documents that constitutes the formal education system bears a significant resemblance to the dynamic equilibrium of a chemical reaction. That is to say, it appears to be subject to Le Châtelier's principle which states that a system in equilibrium, when subject to an external change, adjusts itself to restore that equilibrium. This is not to say that all research is pointless as the system will actively work to prevent the implementation of any transmutations. Rather, the system is robust and therefore is able to adjust slowly to any potential refashioning that emerges from research; researchers need therefore not be afraid of the fruits of their labours but should share their insights from the process openly and widely.

I have been blessed through this process by a loving and understanding wife who has walked with me on this journey through both ice and fire. I have also been blessed with a remarkable team of research supervisors who have challenged my thinking, acted as a voice of reason, but who have never prevented me from choosing my own path to walk. To quote Douglas Adams, "… my methods of navigation have their advantage. I may not have gone where I intended to go, but I think I have ended up where I needed to be.[6]".

In the quixotic hope that future doctoral researchers may stumble upon this thesis and read these terminal words I conclude with another Douglas Adams (mis)quote[7]:

THINK THE UNTHINKABLE, DO THE UNDOABLE. PREPARE TO GRAPPLE WITH THE INEFFABLE ITSELF, AND SEE IF YOU MAY NOT EFF IT AFTER ALL.

WE HAVE DIFFERENT GIFTS, ACCORDING TO THE GRACE GIVEN TO EACH OF US. IF YOUR GIFT IS PROPHESYING, THEN PROPHESY IN ACCORDANCE WITH YOUR FAITH; IF IT IS SERVING, THEN SERVE; IF IT IS TEACHING, THEN TEACH.

- ROMANS 12:6-7

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6 Dirk Gently to Kate in " The Long Dark Tea-Time of the Soul" ISBN 9780671742515
7 Dirk Gently to his assistant Janice in "Dirk Gently's Holistic Detective Agency" ISBN 9780330301626

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Appendix A: Composite student enrolment data for all Australia 1992-2014

The following data were collated from the Australian state and territory curriculum authorities' published annual raw enrolment data for Year 12 courses. International Baccalaureate Diploma Programme enrolment data were also included in this dataset. Overall Student enrolment numbers were compiled from Australian Bureau of Statistics data where not available from curriculum authorities, for example in determining the number of Year 10 and Year 8 students in a given cohort. Where data is unavailable a '-' is used. The data are organised in the following tables by Key Learning Areas. Note that not all courses are available in all states and jurisdictions and that courses have changed name and content over the period for which data is available.

Table A.1: Numbers of students enrolled to complete a course of study in all Australian states and territories.

Year	Overall Enrolment Numbers								
	Year 12			Year 10			Year 8		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	189121	89872	99249	237273	120920	116353	239630	122674	116956
1993	182309	86314	95995	233086	118654	114432	240260	123283	116977
1994	174236	81880	92356	230427	116729	113698	246980	126671	120309
1995	168538	78809	89729	230533	117235	113298	252375	129145	123230
1996	171734	80581	91153	237687	120718	116969	255299	129999	125300
1997	175050	82418	92632	243946	123516	120430	256443	131205	125238
1998	180120	84578	95542	246799	124889	121910	258003	131734	126269
1999	187391	87407	99984	250317	126540	123777	256839	131278	125561
2000	186226	86722	99504	252507	127548	124959	255707	130895	124812
2001	187797	88234	99563	253199	128493	124706	257991	131507	126484
2002	192877	90706	102171	251737	127989	123748	262928	134267	128661
2003	195815	92590	103225	254595	129048	125547	266747	136425	130322
2004	194579	91927	102652	259236	131559	127677	271471	138482	132989
2005	194105	91420	102685	263383	134005	129378	271787	139041	132746
2006	195627	91737	103890	269495	136873	132622	274951	140460	134491
2007	197730	93356	104374	271448	137942	133506	275728	141127	134601
2008	201257	94415	106842	275581	140077	135504	277649	142022	135627
2009	207576	98724	108852	277059	140820	136239	275276	140538	134738
2010	214475	102263	112212	282516	144223	138293	263689	134593	129096

Year	Overall Enrolment Numbers								
	Year 12			Year 10			Year 8		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2011	217572	104358	113214	281096	143470	137626	274207	140121	134086
2012	219905	105518	114387	266642	135515	131127	276005	140986	135019
2013	219952	106198	113754	278239	141956	136283	279336	142313	137023
2014	217186	104899	112287	280573	142944	137629	276887	141368	135519

Year	Sciences								
	Physics			Chemistry			Biology		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	39341	28114	11227	43262	23836	19426	66680	24043	42637
1993	36731	26298	10433	41322	22369	18953	62303	22552	39751
1994	32712	23482	9230	37932	20142	17790	54785	19682	35103
1995	30901	21972	8929	35829	18745	17084	51005	17889	33116
1996	30353	21549	8804	34712	17909	16803	49628	17116	32512
1997	31548	22064	9484	35817	18377	17440	49239	17004	32235
1998	31927	22534	9393	35849	18485	17364	50887	17361	33526
1999	32131	22769	9362	36073	18495	17578	51782	17487	34295
2000	31347	22203	9144	35806	18074	17732	51474	16999	34475
2001	30985	22176	8809	33569	16849	16720	47665	15859	31806
2002	30758	22274	8484	33532	16597	16935	47670	15615	32055
2003	31522	22938	8584	34581	17341	17240	48392	16173	32219
2004	31881	23262	8619	35713	18177	17536	48601	16558	32043
2005	29791	21738	8053	36330	18450	17880	48757	16857	31900
2006	29033	21241	7792	36142	18218	17924	49344	17387	31957
2007	29359	21732	7627	36448	18935	17513	49050	17481	31569
2008	29991	22014	7977	36640	18720	17920	49610	17381	32229
2009	30060	22026	8034	36852	18668	18184	50510	17840	32670
2010	30712	22907	7805	37600	19050	18550	51873	18434	33439
2011	30539	23114	7425	38806	19874	18932	53185	19037	34148

Year	Sciences								
	Physics			Chemistry			Biology		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2012	30877	23479	7398	39187	20287	18900	53802	19331	34471
2013	31144	23769	7375	39776	20400	19376	53863	19243	34620
2014	31015	23885	7130	39529	20340	19189	53771	19237	34534

Year	Sciences								
	Earth Science			Multidisciplinary Science					
	Total	Male	Female	Total	Male	Female			
1992	2534	1647	887	16301	9360	6941			
1993	2021	1350	671	15707	8745	6962			
1994	1472	890	582	15679	8791	6888			
1995	1253	829	424	14101	7939	6162			
1996	1101	701	400	13672	7651	6021			
1997	948	600	348	13140	6893	6247			
1998	1001	587	414	13329	7356	5973			
1999	1049	610	439	13279	7342	5937			
2000	949	630	319	13235	7329	5906			
2001	1874	1052	822	12732	6927	5805			
2002	1847	1009	838	12633	6901	5732			
2003	1895	1066	829	13133	7278	5855			
2004	1995	1095	900	12220	6528	5692			
2005	2101	1179	922	12046	6326	5720			
2006	1931	1126	805	10295	5311	4984			
2007	2065	1175	890	10603	5523	5080			
2008	2201	1256	945	11380	5815	5565			
2009	2669	1456	1213	11544	5874	5670			
2010	2971	1560	1411	11112	5663	5449			
2011	2976	1550	1426	11573	5896	5677			

Year	Sciences								
	Earth Science			Multidisciplinary Science					
	Total	Male	Female	Total	Male	Female			
2012	3470	1832	1638	9386	5002	4384			
2013	3165	1647	1518	9492	4888	4604			
2014	3162	1700	1462	10004	5218	4786			

Year	Mathematics								
	Entry Mathematics			Intermediate Mathematics			Advanced Mathematics		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	-	-	-	-	-	-	-	-	-
1993	-	-	-	-	-	-	-	-	-
1994	66792	30599	36193	66046	33983	32063	26833	16951	9882
1995	68044	31203	36841	59749	30545	29204	25422	16028	9394
1996	69203	31209	37994	59384	30493	28891	24026	15119	8907
1997	70396	32194	38202	60353	30910	29443	24342	15148	9194
1998	72487	32861	39626	60439	31046	29393	24011	15100	8911
1999	78190	34818	43372	60225	31166	29059	23929	15163	8766
2000	81559	36460	45099	59226	30737	28489	23084	14486	8598
2001	78883	35890	42993	64831	34080	30751	22329	14043	8286
2002	83309	38315	44994	64407	34118	30289	22517	14108	8409
2003	88408	41310	47098	65714	35305	30409	22983	14351	8632
2004	86966	40362	46604	64627	35049	29578	23617	14639	8978
2005	87440	40715	46725	63010	33786	29224	22246	13778	8468
2006	89631	41652	47979	60597	32512	28085	21247	13026	8221
2007	93414	43373	50041	59500	32661	26839	20625	12915	7710
2008	96449	44986	51463	59756	32360	27396	21218	13276	7942
2009	97602	46416	51186	59803	32400	27403	21427	13360	8067
2010	102941	48842	54099	59468	32552	26916	21509	13545	7964
2011	106114	50660	55454	58839	32284	26555	20622	12991	7631
2012	106900	51095	55805	59144	32724	26420	20789	13309	7480

Year	Mathematics								
	Entry Mathematics			Intermediate Mathematics			Advanced Mathematics		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2013	106283	50650	55633	59196	32870	26326	21105	13465	7640
2014	102769	48882	53887	58781	32535	26246	21269	13685	7584

Year	Technologies								
	Design Technology			Engineering			Food Technology		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	18089	12194	5895	5104	4745	359	10984	912	10072
1993	17169	11841	5328	3677	3444	233	10096	834	9262
1994	17011	11409	5602	3097	2898	199	7658	953	6705
1995	16742	11791	4951	2219	2069	150	7778	1107	6671
1996	17146	11403	5743	2151	2010	141	7693	1178	6515
1997	16519	11438	5081	1882	1758	124	7410	1140	6270
1998	17007	11763	5244	1766	1653	113	7558	1141	6417
1999	17550	12118	5432	1772	1663	109	7623	1083	6540
2000	18283	12306	5977	1551	1455	96	7305	1020	6285
2001	18558	13841	4717	2946	2844	102	10713	1755	8958
2002	18796	13629	5167	2860	2772	88	10549	1956	8593
2003	20477	14588	5889	2765	2656	109	12107	2397	9710
2004	21667	14940	6727	3006	2931	75	12330	2571	9759
2005	21197	14571	6626	2924	2814	110	11833	2602	9231
2006	22278	15110	7168	3053	2918	135	12028	2649	9379
2007	22454	15159	7295	3397	3239	158	11897	2602	9295
2008	21647	14349	7298	3828	3636	192	12312	2635	9677
2009	22642	15190	7452	3581	3396	185	12249	2682	9567
2010	23563	15684	7879	3868	3651	217	12738	2908	9830
2011	24136	16319	7817	3852	3671	181	13724	2977	10747

Year	Technologies								
	Design Technology			Engineering			Food Technology		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2012	24934	16791	8143	4431	4221	210	13848	2962	10886
2013	24992	17021	7971	4442	4219	223	13635	2838	10797
2014	23597	16435	7162	4329	4080	249	13614	2910	10704

Year	Technologies								
	Food and Fibre Production			Digital Technologies					
	Total	Male	Female	Total	Male	Female			
1992	4049	2688	1361	25889	13844	12045			
1993	3969	2605	1364	27044	14880	12164			
1994	3769	2460	1309	28300	15799	12501			
1995	4018	2541	1477	31021	17927	13094			
1996	3554	2199	1355	33082	19660	13422			
1997	3756	2286	1470	34632	21215	13417			
1998	3377	2208	1169	36629	22694	13935			
1999	3718	2244	1474	38605	24450	14155			
2000	2953	1792	1161	42260	27090	15170			
2001	2791	1715	1076	40197	27390	12807			
2002	2992	1815	1177	38382	26810	11572			
2003	2774	1650	1124	35590	25893	9697			
2004	2617	1573	1044	29523	22420	7103			
2005	2506	1448	1058	25277	19302	5975			
2006	2580	1496	1084	22232	17085	5147			
2007	2350	1316	1034	21048	16257	4791			
2008	2388	1278	1110	20096	15252	4844			
2009	2328	1166	1162	19829	15283	4546			
2010	2634	1309	1325	18686	14464	4222			
2011	2419	1163	1256	19275	14513	4762			

Year	Technologies								
	Food and Fibre Production			Digital Technologies					
	Total	Male	Female	Total	Male	Female			
2012	2584	1239	1345	17873	13964	3909			
2013	2578	1205	1373	16760	13083	3677			
2014	2535	1204	1331	15797	12494	3303			

Year	Humanities and Social Sciences								
	Economics			History			Geography		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	42145	22253	19892	46238	18007	28231	36474	18693	17781
1993	33430	18087	15343	40637	16326	24311	32798	16737	16061
1994	27226	14739	12487	37021	14718	22303	29907	15534	14373
1995	24078	13203	10875	35594	14099	21495	26884	13836	13048
1996	21572	11732	9840	35068	13685	21383	25318	12765	12553
1997	17828	9894	7934	33528	12992	20536	22075	11271	10804
1998	16825	9463	7362	33837	12535	21302	21995	11266	10729
1999	16970	9640	7330	35584	13923	21661	22183	10585	11598
2000	17318	10057	7261	36277	14029	22248	21785	10903	10882
2001	16910	9851	7059	37543	14701	22842	21011	10315	10696
2002	16738	10024	6714	38300	15530	22770	20642	10329	10313
2003	16569	9930	6639	41407	16703	24704	19840	10183	9657
2004	16287	9766	6521	41175	16906	24269	16972	8647	8325
2005	15495	9393	6102	43944	17953	25991	17146	8609	8537
2006	15031	9098	5933	44549	18618	25931	16149	8154	7995
2007	15181	9040	6141	44305	18240	26065	16181	7923	8258
2008	14261	8573	5688	44137	18307	25830	15218	7480	7738
2009	14825	8854	5971	44776	18823	25953	15461	7523	7938
2010	14701	8892	5809	45398	19156	26242	15368	7578	7790
2011	13234	7889	5345	44958	18821	26137	14158	7170	6988

Year	Humanities and Social Sciences								
	Economics			History			Geography		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2012	12852	7944	4908	45857	19323	26534	14551	7269	7282
2013	13161	8149	5012	44531	18759	25772	14116	6901	7215
2014	12189	7625	4564	43600	18761	24839	13647	6767	6880

Year	Humanities and Social Sciences								
	Religious Studies			Business Studies			Legal Studies		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1990	89	12	77	-	-	-	1819	828	991
1991	2219	854	1365	1818	924	894	24188	10307	13881
1992	2508	868	1640	10228	5182	5046	29049	11967	17082
1993	2704	988	1716	13500	7098	6402	28869	11693	17176
1994	3823	1666	2157	16436	8514	7922	27829	10981	16848
1995	4628	2007	2621	19112	9899	9213	25318	9644	15674
1996	4871	2082	2789	21413	11068	10345	24122	9324	14798
1997	5559	2465	3094	19813	10288	9525	24229	9163	15066
1998	5986	2517	3469	21375	11150	10225	24053	9255	14798
1999	6774	2823	3951	24036	12351	11685	24644	9306	15338
2000	7328	3112	4216	30850	14620	16230	25808	9933	15875
2001	8197	3454	4743	36476	17183	19293	25560	9954	15606
2002	9523	4097	5426	37294	17920	19374	25022	9626	15396
2003	10330	4434	5896	39077	18800	20277	26032	9952	16080
2004	10642	4404	6238	39710	19166	20544	26887	10033	16854
2005	11189	4382	6807	39846	19276	20570	27654	10343	17311
2006	11032	4239	6793	40356	19324	21032	26403	9888	16515
2007	11093	4184	6909	40347	19245	21102	25943	9786	16157
2008	11638	4494	7144	40959	19355	21604	24900	9497	15403
2009	12018	4658	7360	40791	19555	21236	25188	9594	15594

Year	Humanities and Social Sciences								
	Religious Studies			Business Studies			Legal Studies		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2010	14448	5526	8922	41162	19565	21597	25515	9720	15795
2011	14148	5494	8654	38320	18203	20117	26007	9871	16136
2012	15577	6133	9444	40457	19420	21037	27134	10223	16911
2013	14792	5935	8857	40803	19594	21209	27069	10221	16848
2014	14722	5933	8789	40293	19730	20563	27296	10410	16886

Year	Humanities and Social Sciences								
	Psychology			Sociology					
	Total	Male	Female	Total	Male	Female			
1990	2	1	1	-	-	-			
1991	662	161	501	3833	879	2954			
1992	8508	1907	6601	4302	1058	3244			
1993	10236	2329	7907	3980	860	3120			
1994	10313	2251	8062	3912	767	3145			
1995	10867	2286	8581	3658	768	2890			
1996	11960	2629	9331	3569	641	2928			
1997	12982	2681	10301	3882	735	3147			
1998	13130	2763	10367	3885	736	3149			
1999	13503	2861	10642	4040	756	3284			
2000	13797	2954	10843	3972	693	3279			
2001	14786	3275	11511	4469	775	3694			
2002	15155	3400	11755	4641	743	3898			
2003	18775	3615	15160	6498	1341	5157			
2004	16389	3845	12544	6186	1355	4831			
2005	17015	4219	12796	6438	1352	5086			
2006	17857	4483	13374	7204	1618	5586			
2007	17995	4591	13404	7479	1636	5843			
2008	19158	4982	14176	7637	1764	5873			
2009	19773	5353	14420	7531	1708	5823			

Year	Humanities and Social Sciences								
	Psychology			Sociology					
	Total	Male	Female	Total	Male	Female			
2010	21059	5749	15310	7608	1699	5909			
2011	20244	5629	14615	6884	1440	5444			
2012	20513	5701	14812	6937	1493	5444			
2013	20214	5608	14606	6866	1492	5374			
2014	20948	5945	15003	7484	1667	5817			

Year	Creative and Performing Arts								
	Visual Arts			Drama			Music		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	25373	9177	16196	3634	983	2651	7463	3123	4340
1993	24032	8772	15260	4362	1086	3276	7614	3292	4322
1994	21914	8067	13847	5434	1349	4085	6336	2857	3479
1995	21536	7723	13813	6499	1594	4905	6021	2711	3310
1996	21903	7909	13994	8932	2231	6701	6030	2693	3337
1997	18696	6812	11884	10767	2699	8068	6881	3113	3768
1998	19235	6655	12580	11407	2866	8541	8159	3482	4677
1999	19863	6660	13203	12642	3260	9382	8733	3851	4882
2000	20606	6618	13988	13848	3649	10199	9009	3984	5025
2001	23535	6983	16552	14626	3910	10716	9296	4118	5178
2002	23619	6627	16992	14970	3926	11044	8999	4134	4865
2003	23683	6846	16837	15840	4240	11600	9517	4453	5064
2004	22969	6560	16409	15571	4307	11264	9691	4535	5156
2005	22846	6449	16397	15955	4576	11379	10631	5071	5560
2006	23316	6737	16579	15849	4556	11293	11345	5562	5783
2007	23899	6803	17096	17164	4601	12563	12126	6229	5897
2008	23702	6445	17257	14874	4226	10648	12647	6590	6057
2009	23447	6251	17196	16578	4556	12022	12930	6850	6080
2010	23935	6388	17547	14646	4340	10306	12740	6790	5950
2011	24260	6500	17760	15107	4469	10638	12738	6642	6096

Year	Creative and Performing Arts								
	Visual Arts			Drama			Music		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2012	23976	6140	17836	15211	4463	10748	12959	6654	6305
2013	22639	5824	16815	14022	4173	9849	12308	6159	6149
2014	21332	5356	15976	13933	4122	9811	11951	5934	6017

Year	Health								
	Personal Development, Health and Physical Education								
	Total	Male	Female						
1992	19134	11154	7980						
1993	22786	12791	9995						
1994	22207	12351	9856						
1995	21728	12168	9560						
1996	22645	12514	10131						
1997	23689	13105	10584						
1998	24350	13098	11252						
1999	24821	13202	11619						
2000	21306	10965	10341						
2001	24609	12873	11736						
2002	26855	14173	12682						
2003	30560	16562	13998						
2004	31072	16704	14368						
2005	32349	17455	14894						
2006	34702	18576	16126						
2007	35971	19355	16616						
2008	38554	20607	17947						
2009	39099	20855	18244						
2010	40900	22173	18727						

Year	Health								
	Personal Development, Health and Physical Education								
	Total	Male	Female						
2011	40559	22151	18408						
2012	39324	21775	17549						
2013	39587	21884	17703						
2014	40513	21893	18620						

Year	Languages Other Than English								
	French			German			Italian		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	4399	1033	3366	2720	749	1971	2187	593	1594
1993	4332	997	3335	2609	717	1892	2100	521	1579
1994	4422	1031	3391	2679	774	1905	2169	598	1571
1995	4410	1033	3377	2721	753	1968	2204	625	1579
1996	4235	994	3241	2676	758	1918	2082	572	1510
1997	4032	954	3078	2739	832	1907	2105	584	1521
1998	4310	1019	3291	2849	824	2025	2013	546	1467
1999	4159	966	3193	2754	805	1949	1875	530	1345
2000	4295	1039	3256	2787	865	1922	1925	535	1390
2001	4279	944	3335	2751	813	1938	1991	538	1453
2002	4199	999	3200	2657	804	1853	2143	558	1585
2003	4446	1059	3387	2607	832	1775	2298	634	1664
2004	4617	1152	3465	2620	850	1770	2269	618	1651
2005	4585	1164	3421	2537	882	1655	2243	622	1621
2006	5004	1283	3721	2423	805	1618	2527	663	1864
2007	5104	1311	3793	2422	875	1547	2405	622	1783
2008	5202	1329	3873	2302	824	1478	2217	625	1592
2009	5140	1491	3649	2094	748	1346	2300	636	1664
2010	5448	1476	3972	2089	731	1358	2288	656	1632
2011	5398	1521	3877	2007	767	1240	2297	670	1627

Year	Languages Other Than English								
	French			German			Italian		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2012	5839	1579	4260	2066	777	1289	2465	736	1729
2013	5640	1506	4134	1926	734	1192	2402	752	1650
2014	5345	1418	3927	2032	743	1289	2160	638	1522

Year	Languages Other Than English								
	Spanish			Japanese			Chinese		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	654	271	383	3863	999	2864	1714	807	907
1993	734	297	437	4381	1187	3194	2238	1079	1159
1994	799	326	473	5456	1388	4068	2616	1310	1306
1995	749	271	478	5165	1425	3740	2512	1296	1216
1996	763	285	478	5378	1389	3989	2361	1166	1195
1997	733	267	466	5303	1342	3961	2500	1231	1269
1998	732	269	463	5503	1496	4007	2450	1194	1256
1999	663	219	444	5163	1410	3753	2254	1079	1175
2000	633	232	401	5149	1399	3750	2583	1263	1320
2001	715	257	458	5060	1548	3512	3556	1660	1896
2002	753	270	483	5135	1497	3638	4197	2028	2169
2003	812	311	501	4990	1610	3380	5193	2531	2662
2004	841	290	551	5097	1668	3429	5946	2943	3003
2005	835	269	566	5022	1659	3363	5495	2685	2810
2006	848	311	537	5012	1824	3188	5236	2543	2693
2007	903	309	594	4846	1737	3109	5216	2511	2705
2008	952	319	633	4954	1689	3265	5337	2564	2773
2009	914	326	588	5056	1799	3257	6084	2919	3165
2010	1031	350	681	5055	1699	3356	5758	2759	2999
2011	987	375	612	4878	1812	3066	4871	2313	2558

Year	Languages Other Than English								
	Spanish			Japanese			Chinese		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2012	1165	410	755	5080	1907	3173	5132	2512	2620
2013	1053	341	712	4704	1716	2988	5061	2393	2668
2014	1150	388	762	4671	1727	2944	5207	2423	2784

Year	Vocational Education and Training								
	Hospitality			Business Services			Retail Services		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	-	-	-	-	-	-	-	-	-
1993	75	17	58	-	-	-	19	5	14
1994	254	63	191	-	-	-	139	54	85
1995	611	191	420	-	-	-	293	132	161
1996	1686	490	1196	-	-	-	314	129	185
1997	2477	754	1723	-	-	-	281	102	179
1998	5996	1807	4189	279	82	197	439	165	274
1999	8184	2637	5547	260	78	182	571	239	332
2000	8788	2607	6181	964	202	762	482	204	278
2001	12905	3564	9341	3628	645	2983	1784	654	1130
2002	14491	4166	10325	4033	634	3399	2140	739	1401
2003	14382	4207	10175	3959	782	3177	2361	809	1552
2004	14419	4264	10155	4480	996	3484	2682	855	1827
2005	15192	4640	10552	4770	1184	3586	3176	1032	2144
2006	15391	4848	10543	5557	1529	4028	4686	1267	3419
2007	12963	4113	8850	5362	1552	3810	5013	1331	3682
2008	12788	4061	8727	4571	1210	3361	5600	1541	4059
2009	12079	3879	8200	4545	1308	3237	4048	973	3075
2010	10997	3520	7477	4129	1168	2961	4374	945	3429
2011	13574	4383	9191	5288	1913	3375	4424	878	3546

Year	Vocational Education and Training								
	Hospitality			Business Services			Retail Services		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2012	13064	3972	9092	5019	1974	3045	1944	617	1327
2013	11298	3522	7776	3221	972	2249	2629	801	1828
2014	10420	3009	7411	2394	664	1730	1877	576	1301

Year	Vocational Education and Training								
	Construction			Information Technology					
	Total	Male	Female	Total	Male	Female			
1992	-	-	-	-	-	-			
1993	-	-	-	-	-	-			
1994	-	-	-	-	-	-			
1995	-	-	-	-	-	-			
1996	-	-	-	-	-	-			
1997	-	-	-	-	-	-			
1998	725	706	19	2130	1124	1006			
1999	914	891	23	3554	1951	1603			
2000	1281	1252	29	4571	2614	1957			
2001	3018	2978	40	9924	5943	3981			
2002	3233	3191	42	11350	7188	4162			
2003	3067	3020	47	11196	7401	3795			
2004	3248	3202	46	9598	6366	3232			
2005	3647	3570	77	8884	5947	2937			
2006	3190	3137	53	7145	4938	2207			
2007	3597	3551	46	6828	4837	1991			
2008	4135	4050	85	6546	4631	1915			
2009	4824	4742	82	6161	4361	1800			
2010	4367	4284	83	5522	3930	1592			
2011	5264	5093	171	4802	3475	1327			

Year	Vocational Education and Training								
	Construction			Information Technology					
	Total	Male	Female	Total	Male	Female			
2012	4181	4064	117	3958	2782	1176			
2013	4594	4463	131	3603	2550	1053			
2014	3906	3776	130	2491	1905	586			

Table A.2: Student Participation rates for various courses of study in all Australian states and territories.

Year	Sciences								
	Physics			Chemistry			Biology		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	20.802%	31.282%	11.312%	22.875%	26.522%	19.573%	35.258%	26.752%	42.960%
1993	20.148%	30.468%	10.868%	22.666%	25.916%	19.744%	34.174%	26.128%	41.409%
1994	18.775%	28.679%	9.994%	21.770%	24.599%	19.262%	31.443%	24.038%	38.008%
1995	18.335%	27.880%	9.951%	21.259%	23.785%	19.040%	30.263%	22.699%	36.907%
1996	17.674%	26.742%	9.658%	20.213%	22.225%	18.434%	28.898%	21.241%	35.668%
1997	18.022%	26.771%	10.238%	20.461%	22.297%	18.827%	28.129%	20.631%	34.799%
1998	17.725%	26.643%	9.831%	19.903%	21.856%	18.174%	28.252%	20.527%	35.090%
1999	17.147%	26.049%	9.363%	19.250%	21.160%	17.581%	27.633%	20.006%	34.300%
2000	16.833%	25.602%	9.190%	19.227%	20.841%	17.820%	27.641%	19.602%	34.647%
2001	16.499%	25.133%	8.848%	17.875%	19.096%	16.793%	25.381%	17.974%	31.946%
2002	15.947%	24.556%	8.304%	17.385%	18.298%	16.575%	24.715%	17.215%	31.374%
2003	16.098%	24.774%	8.316%	17.660%	18.729%	16.701%	24.713%	17.467%	31.212%
2004	16.385%	25.305%	8.396%	18.354%	19.773%	17.083%	24.978%	18.012%	31.215%
2005	15.348%	23.778%	7.842%	18.717%	20.182%	17.412%	25.119%	18.439%	31.066%
2006	14.841%	23.154%	7.500%	18.475%	19.859%	17.253%	25.224%	18.953%	30.760%
2007	14.848%	23.279%	7.307%	18.433%	20.283%	16.779%	24.807%	18.725%	30.246%
2008	14.902%	23.316%	7.466%	18.206%	19.827%	16.772%	24.650%	18.409%	30.165%
2009	14.481%	22.311%	7.381%	17.753%	18.909%	16.705%	24.333%	18.071%	30.013%
2010	14.320%	22.400%	6.956%	17.531%	18.628%	16.531%	24.186%	18.026%	29.800%

Year	Sciences								
	Physics			Chemistry			Biology		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2011	14.036%	22.149%	6.558%	17.836%	19.044%	16.722%	24.445%	18.242%	30.162%
2012	14.041%	22.251%	6.468%	17.820%	19.226%	16.523%	24.466%	18.320%	30.135%
2013	14.159%	22.382%	6.483%	18.084%	19.209%	17.033%	24.489%	18.120%	30.434%
2014	14.280%	22.770%	6.350%	18.201%	19.390%	17.089%	24.758%	18.339%	30.755%

Year	Sciences								
	Earth Science			Multidisciplinary Science					
	Total	Male	Female	Total	Male	Female			
1992	1.340%	1.833%	0.894%	8.619%	10.415%	6.994%			
1993	1.109%	1.564%	0.699%	8.616%	10.132%	7.252%			
1994	0.845%	1.087%	0.630%	8.999%	10.736%	7.458%			
1995	0.743%	1.052%	0.473%	8.367%	10.074%	6.867%			
1996	0.641%	0.870%	0.439%	7.961%	9.495%	6.605%			
1997	0.542%	0.728%	0.376%	7.506%	8.363%	6.744%			
1998	0.556%	0.694%	0.433%	7.400%	8.697%	6.252%			
1999	0.560%	0.698%	0.439%	7.086%	8.400%	5.938%			
2000	0.510%	0.726%	0.321%	7.107%	8.451%	5.935%			
2001	0.998%	1.192%	0.826%	6.780%	7.851%	5.830%			
2002	0.958%	1.112%	0.820%	6.550%	7.608%	5.610%			
2003	0.968%	1.151%	0.803%	6.707%	7.860%	5.672%			
2004	1.025%	1.191%	0.877%	6.280%	7.101%	5.545%			
2005	1.082%	1.290%	0.898%	6.206%	6.920%	5.570%			
2006	0.987%	1.227%	0.775%	5.263%	5.789%	4.797%			
2007	1.044%	1.259%	0.853%	5.362%	5.916%	4.867%			
2008	1.094%	1.330%	0.884%	5.654%	6.159%	5.209%			
2009	1.286%	1.475%	1.114%	5.561%	5.950%	5.209%			
2010	1.385%	1.525%	1.257%	5.181%	5.538%	4.856%			
2011	1.368%	1.485%	1.260%	5.319%	5.650%	5.014%			

Year	Sciences								
	Earth Science			Multidisciplinary Science					
	Total	Male	Female	Total	Male	Female			
2012	1.578%	1.736%	1.432%	4.268%	4.740%	3.833%			
2013	1.439%	1.551%	1.334%	4.315%	4.603%	4.047%			
2014	1.456%	1.621%	1.302%	4.606%	4.974%	4.262%			

Year	Mathematics								
	Entry Mathematics			Intermediate Mathematics			Advanced Mathematics		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	-	-	-	-	-	-	-	-	-
1993	-	-	-	-	-	-	-	-	-
1994	38.334%	37.371%	39.189%	37.906%	41.503%	34.717%	15.400%	20.702%	10.700%
1995	40.373%	39.593%	41.058%	35.451%	38.758%	32.547%	15.084%	20.338%	10.469%
1996	40.297%	38.730%	41.682%	34.579%	37.841%	31.695%	13.990%	18.762%	9.771%
1997	40.215%	39.062%	41.241%	34.478%	37.504%	31.785%	13.906%	18.379%	9.925%
1998	40.244%	38.853%	41.475%	33.555%	36.707%	30.764%	13.331%	17.853%	9.327%
1999	41.726%	39.834%	43.379%	32.139%	35.656%	29.064%	12.770%	17.348%	8.767%
2000	43.796%	42.042%	45.324%	31.803%	35.443%	28.631%	12.396%	16.704%	8.641%
2001	42.004%	40.676%	43.182%	34.522%	38.625%	30.886%	11.890%	15.916%	8.322%
2002	43.193%	42.241%	44.038%	33.393%	37.614%	29.645%	11.674%	15.554%	8.230%
2003	45.149%	44.616%	45.627%	33.559%	38.130%	29.459%	11.737%	15.500%	8.362%
2004	44.694%	43.907%	45.400%	33.214%	38.127%	28.814%	12.137%	15.925%	8.746%
2005	45.048%	44.536%	45.503%	32.462%	36.957%	28.460%	11.461%	15.071%	8.247%
2006	45.817%	45.404%	46.183%	30.976%	35.440%	27.033%	10.861%	14.199%	7.913%
2007	47.243%	46.460%	47.944%	30.092%	34.985%	25.714%	10.431%	13.834%	7.387%
2008	47.923%	47.647%	48.167%	29.691%	34.274%	25.642%	10.543%	14.061%	7.433%
2009	47.020%	47.016%	47.023%	28.810%	32.819%	25.175%	10.322%	13.533%	7.411%
2010	47.997%	47.761%	48.211%	27.727%	31.832%	23.987%	10.029%	13.245%	7.097%
2011	48.772%	48.544%	48.982%	27.043%	30.936%	23.456%	9.478%	12.448%	6.740%

Year	Mathematics								
	Entry Mathematics			Intermediate Mathematics			Advanced Mathematics		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2012	48.612%	48.423%	48.786%	26.895%	31.013%	23.097%	9.454%	12.613%	6.539%
2013	48.321%	47.694%	48.906%	26.913%	30.952%	23.143%	9.595%	12.679%	6.716%
2014	47.318%	46.599%	47.990%	27.065%	31.016%	23.374%	9.793%	13.046%	6.754%

Year	Technologies								
	Design Technology			Engineering			Food Technology		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	9.565%	13.568%	5.940%	2.699%	5.280%	0.362%	5.808%	1.015%	10.148%
1993	9.418%	13.719%	5.550%	2.017%	3.990%	0.243%	5.538%	0.966%	9.648%
1994	9.763%	13.934%	6.066%	1.777%	3.539%	0.215%	4.395%	1.164%	7.260%
1995	9.934%	14.961%	5.518%	1.317%	2.625%	0.167%	4.615%	1.405%	7.435%
1996	9.984%	14.151%	6.300%	1.253%	2.494%	0.155%	4.480%	1.462%	7.147%
1997	9.437%	13.878%	5.485%	1.075%	2.133%	0.134%	4.233%	1.383%	6.769%
1998	9.442%	13.908%	5.489%	0.980%	1.954%	0.118%	4.196%	1.349%	6.716%
1999	9.365%	13.864%	5.433%	0.946%	1.903%	0.109%	4.068%	1.239%	6.541%
2000	9.818%	14.190%	6.007%	0.833%	1.678%	0.096%	3.923%	1.176%	6.316%
2001	9.882%	15.687%	4.738%	1.569%	3.223%	0.102%	5.705%	1.989%	8.997%
2002	9.745%	15.025%	5.057%	1.483%	3.056%	0.086%	5.469%	2.156%	8.410%
2003	10.457%	15.755%	5.705%	1.412%	2.869%	0.106%	6.183%	2.589%	9.407%
2004	11.135%	16.252%	6.553%	1.545%	3.188%	0.073%	6.337%	2.797%	9.507%
2005	10.920%	15.939%	6.453%	1.506%	3.078%	0.107%	6.096%	2.846%	8.990%
2006	11.388%	16.471%	6.900%	1.561%	3.181%	0.130%	6.148%	2.888%	9.028%
2007	11.356%	16.238%	6.989%	1.718%	3.470%	0.151%	6.017%	2.787%	8.905%
2008	10.756%	15.198%	6.831%	1.902%	3.851%	0.180%	6.118%	2.791%	9.057%
2009	10.908%	15.386%	6.846%	1.725%	3.440%	0.170%	5.901%	2.717%	8.789%
2010	10.986%	15.337%	7.022%	1.803%	3.570%	0.193%	5.939%	2.844%	8.760%
2011	11.093%	15.638%	6.905%	1.770%	3.518%	0.160%	6.308%	2.853%	9.493%

Year	Technologies								
	Design Technology			Engineering			Food Technology		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2012	11.339%	15.913%	7.119%	2.015%	4.000%	0.184%	6.297%	2.807%	9.517%
2013	11.362%	16.028%	7.007%	2.020%	3.973%	0.196%	6.199%	2.672%	9.492%
2014	10.865%	15.667%	6.378%	1.993%	3.889%	0.222%	6.268%	2.774%	9.533%

Year	Technologies								
	Food and Fibre Production			Digital Technologies					
	Total	Male	Female	Total	Male	Female			
1992	2.141%	2.991%	1.371%	13.689%	15.404%	12.136%			
1993	2.177%	3.018%	1.421%	14.834%	17.239%	12.671%			
1994	2.163%	3.004%	1.417%	16.242%	19.295%	13.536%			
1995	2.384%	3.224%	1.646%	18.406%	22.747%	14.593%			
1996	2.069%	2.729%	1.487%	19.264%	24.398%	14.725%			
1997	2.146%	2.774%	1.587%	19.784%	25.741%	14.484%			
1998	1.875%	2.611%	1.224%	20.336%	26.832%	14.585%			
1999	1.984%	2.567%	1.474%	20.601%	27.973%	14.157%			
2000	1.586%	2.066%	1.167%	22.693%	31.238%	15.246%			
2001	1.486%	1.944%	1.081%	21.404%	31.042%	12.863%			
2002	1.551%	2.001%	1.152%	19.900%	29.557%	11.326%			
2003	1.417%	1.782%	1.089%	18.175%	27.965%	9.394%			
2004	1.345%	1.711%	1.017%	15.173%	24.389%	6.919%			
2005	1.291%	1.584%	1.030%	13.022%	21.114%	5.819%			
2006	1.319%	1.631%	1.043%	11.364%	18.624%	4.954%			
2007	1.188%	1.410%	0.991%	10.645%	17.414%	4.590%			
2008	1.187%	1.354%	1.039%	9.985%	16.154%	4.534%			
2009	1.122%	1.181%	1.068%	9.553%	15.481%	4.176%			
2010	1.228%	1.280%	1.181%	8.712%	14.144%	3.763%			
2011	1.112%	1.114%	1.109%	8.859%	13.907%	4.206%			

Year	Technologies								
	Food and Fibre Production			Digital Technologies					
	Total	Male	Female	Total	Male	Female			
2012	1.175%	1.174%	1.176%	8.128%	13.234%	3.417%			
2013	1.172%	1.135%	1.207%	7.620%	12.319%	3.232%			
2014	1.167%	1.148%	1.185%	7.273%	11.911%	2.942%			

Year	Humanities and Social Sciences								
	Economics			History			Geography		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	22.285%	24.761%	20.043%	24.449%	20.036%	28.445%	19.286%	20.800%	17.916%
1993	18.337%	20.955%	15.983%	22.290%	18.915%	25.325%	17.990%	19.391%	16.731%
1994	15.626%	18.001%	13.521%	21.248%	17.975%	24.149%	17.165%	18.972%	15.563%
1995	14.286%	16.753%	12.120%	21.119%	17.890%	23.955%	15.951%	17.556%	14.542%
1996	12.561%	14.559%	10.795%	20.420%	16.983%	23.458%	14.743%	15.841%	13.771%
1997	10.185%	12.005%	8.565%	19.153%	15.764%	22.169%	12.611%	13.675%	11.663%
1998	9.341%	11.188%	7.706%	18.786%	14.821%	22.296%	12.211%	13.320%	11.230%
1999	9.056%	11.029%	7.331%	18.989%	15.929%	21.664%	11.838%	12.110%	11.600%
2000	9.299%	11.597%	7.297%	19.480%	16.177%	22.359%	11.698%	12.572%	10.936%
2001	9.004%	11.165%	7.090%	19.991%	16.661%	22.942%	11.188%	11.691%	10.743%
2002	8.678%	11.051%	6.571%	19.857%	17.121%	22.286%	10.702%	11.387%	10.094%
2003	8.462%	10.725%	6.432%	21.146%	18.040%	23.932%	10.132%	10.998%	9.355%
2004	8.370%	10.624%	6.353%	21.161%	18.391%	23.642%	8.722%	9.406%	8.110%
2005	7.983%	10.275%	5.942%	22.639%	19.638%	25.311%	8.833%	9.417%	8.314%
2006	7.683%	9.917%	5.711%	22.772%	20.295%	24.960%	8.255%	8.888%	7.696%
2007	7.678%	9.683%	5.884%	22.407%	19.538%	24.973%	8.183%	8.487%	7.912%
2008	7.086%	9.080%	5.324%	21.931%	19.390%	24.176%	7.561%	7.922%	7.242%
2009	7.142%	8.968%	5.485%	21.571%	19.066%	23.842%	7.448%	7.620%	7.292%
2010	6.854%	8.695%	5.177%	21.167%	18.732%	23.386%	7.165%	7.410%	6.942%
2011	6.083%	7.560%	4.721%	20.664%	18.035%	23.086%	6.507%	6.871%	6.172%

Year	Humanities and Social Sciences								
	Economics			History			Geography		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2012	5.844%	7.529%	4.291%	20.853%	18.313%	23.197%	6.617%	6.889%	6.366%
2013	5.984%	7.673%	4.406%	20.246%	17.664%	22.656%	6.418%	6.498%	6.343%
2014	5.612%	7.269%	4.065%	20.075%	17.885%	22.121%	6.284%	6.451%	6.127%

Year	Humanities and Social Sciences								
	Religious Studies			Business Studies			Legal Studies		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	1.326%	0.966%	1.652%	5.408%	5.766%	5.084%	15.360%	13.316%	17.211%
1993	1.483%	1.145%	1.788%	7.405%	8.223%	6.669%	15.835%	13.547%	17.893%
1994	2.194%	2.035%	2.336%	9.433%	10.398%	8.578%	15.972%	13.411%	18.242%
1995	2.746%	2.547%	2.921%	11.340%	12.561%	10.268%	15.022%	12.237%	17.468%
1996	2.836%	2.584%	3.060%	12.469%	13.735%	11.349%	14.046%	11.571%	16.234%
1997	3.176%	2.991%	3.340%	11.318%	12.483%	10.283%	13.841%	11.118%	16.264%
1998	3.323%	2.976%	3.631%	11.867%	13.183%	10.702%	13.354%	10.943%	15.488%
1999	3.615%	3.230%	3.952%	12.827%	14.130%	11.687%	13.151%	10.647%	15.340%
2000	3.935%	3.588%	4.237%	16.566%	16.858%	16.311%	13.858%	11.454%	15.954%
2001	4.365%	3.915%	4.764%	19.423%	19.474%	19.378%	13.610%	11.281%	15.674%
2002	4.937%	4.517%	5.311%	19.336%	19.756%	18.962%	12.973%	10.612%	15.069%
2003	5.275%	4.789%	5.712%	19.956%	20.305%	19.643%	13.294%	10.748%	15.578%
2004	5.469%	4.791%	6.077%	20.408%	20.849%	20.013%	13.818%	10.914%	16.419%
2005	5.764%	4.793%	6.629%	20.528%	21.085%	20.032%	14.247%	11.314%	16.858%
2006	5.639%	4.621%	6.539%	20.629%	21.065%	20.244%	13.497%	10.779%	15.897%
2007	5.610%	4.482%	6.619%	20.405%	20.615%	20.218%	13.120%	10.482%	15.480%
2008	5.783%	4.760%	6.687%	20.352%	20.500%	20.221%	12.372%	10.059%	14.417%
2009	5.790%	4.718%	6.761%	19.651%	19.808%	19.509%	12.134%	9.718%	14.326%
2010	6.736%	5.404%	7.951%	19.192%	19.132%	19.247%	11.896%	9.505%	14.076%
2011	6.503%	5.265%	7.644%	17.613%	17.443%	17.769%	11.953%	9.459%	14.253%

Year	Humanities and Social Sciences								
	Religious Studies			Business Studies			Legal Studies		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2012	7.084%	5.812%	8.256%	18.397%	18.404%	18.391%	12.339%	9.688%	14.784%
2013	6.725%	5.589%	7.786%	18.551%	18.450%	18.645%	12.307%	9.624%	14.811%
2014	6.779%	5.656%	7.827%	18.552%	18.809%	18.313%	12.568%	9.924%	15.038%

Year	Humanities and Social Sciences								
	Psychology			Sociology					
	Total	Male	Female	Total	Male	Female			
1992	4.499%	2.122%	6.651%	2.275%	1.177%	3.269%			
1993	5.615%	2.698%	8.237%	2.183%	0.996%	3.250%			
1994	5.919%	2.749%	8.729%	2.245%	0.937%	3.405%			
1995	6.448%	2.901%	9.563%	2.170%	0.975%	3.221%			
1996	6.964%	3.263%	10.237%	2.078%	0.795%	3.212%			
1997	7.416%	3.253%	11.120%	2.218%	0.892%	3.397%			
1998	7.290%	3.267%	10.851%	2.157%	0.870%	3.296%			
1999	7.206%	3.273%	10.644%	2.156%	0.865%	3.285%			
2000	7.409%	3.406%	10.897%	2.133%	0.799%	3.295%			
2001	7.873%	3.712%	11.562%	2.380%	0.878%	3.710%			
2002	7.857%	3.748%	11.505%	2.406%	0.819%	3.815%			
2003	9.588%	3.904%	14.686%	3.318%	1.448%	4.996%			
2004	8.423%	4.183%	12.220%	3.179%	1.474%	4.706%			
2005	8.766%	4.615%	12.461%	3.317%	1.479%	4.953%			
2006	9.128%	4.887%	12.873%	3.683%	1.764%	5.377%			
2007	9.101%	4.918%	12.842%	3.782%	1.752%	5.598%			
2008	9.519%	5.277%	13.268%	3.795%	1.868%	5.497%			
2009	9.526%	5.422%	13.247%	3.628%	1.730%	5.349%			
2010	9.819%	5.622%	13.644%	3.547%	1.661%	5.266%			
2011	9.305%	5.394%	12.909%	3.164%	1.380%	4.809%			

Year	Humanities and Social Sciences								
	Psychology			Sociology					
	Total	Male	Female	Total	Male	Female			
2012	9.328%	5.403%	12.949%	3.155%	1.415%	4.759%			
2013	9.190%	5.281%	12.840%	3.122%	1.405%	4.724%			
2014	9.645%	5.667%	13.361%	3.446%	1.589%	5.180%			

Year	Creative and Performing Arts								
	Visual Arts			Drama			Music		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	13.416%	10.211%	16.319%	1.922%	1.094%	2.671%	3.946%	3.475%	4.373%
1993	13.182%	10.163%	15.897%	2.393%	1.258%	3.413%	4.176%	3.814%	4.502%
1994	12.577%	9.852%	14.993%	3.119%	1.648%	4.423%	3.636%	3.489%	3.767%
1995	12.778%	9.800%	15.394%	3.856%	2.023%	5.466%	3.572%	3.440%	3.689%
1996	12.754%	9.815%	15.352%	5.201%	2.769%	7.351%	3.511%	3.342%	3.661%
1997	10.680%	8.265%	12.829%	6.151%	3.275%	8.710%	3.931%	3.777%	4.068%
1998	10.679%	7.868%	13.167%	6.333%	3.389%	8.940%	4.530%	4.117%	4.895%
1999	10.600%	7.620%	13.205%	6.746%	3.730%	9.384%	4.660%	4.406%	4.883%
2000	11.065%	7.631%	14.058%	7.436%	4.208%	10.250%	4.838%	4.594%	5.050%
2001	12.532%	7.914%	16.625%	7.788%	4.431%	10.763%	4.950%	4.667%	5.201%
2002	12.246%	7.306%	16.631%	7.761%	4.328%	10.809%	4.666%	4.558%	4.762%
2003	12.095%	7.394%	16.311%	8.089%	4.579%	11.238%	4.860%	4.809%	4.906%
2004	11.804%	7.136%	15.985%	8.002%	4.685%	10.973%	4.980%	4.933%	5.023%
2005	11.770%	7.054%	15.968%	8.220%	5.005%	11.081%	5.477%	5.547%	5.415%
2006	11.919%	7.344%	15.958%	8.102%	4.966%	10.870%	5.799%	6.063%	5.566%
2007	12.087%	7.287%	16.380%	8.681%	4.928%	12.037%	6.133%	6.672%	5.650%
2008	11.777%	6.826%	16.152%	7.391%	4.476%	9.966%	6.284%	6.980%	5.669%
2009	11.296%	6.332%	15.798%	7.986%	4.615%	11.044%	6.229%	6.939%	5.586%
2010	11.160%	6.247%	15.637%	6.829%	4.244%	9.184%	5.940%	6.640%	5.302%
2011	11.150%	6.229%	15.687%	6.943%	4.282%	9.396%	5.855%	6.365%	5.384%

Year	Creative and Performing Arts								
	Visual Arts			Drama			Music		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2012	10.903%	5.819%	15.593%	6.917%	4.230%	9.396%	5.893%	6.306%	5.512%
2013	10.293%	5.484%	14.782%	6.375%	3.929%	8.658%	5.596%	5.800%	5.406%
2014	9.822%	5.106%	14.228%	6.415%	3.929%	8.737%	5.503%	5.657%	5.359%

Year	Health								
	Personal Development, Health and Physical Education								
	Total	Male	Female						
1992	10.117%	12.411%	8.040%						
1993	12.499%	14.819%	10.412%						
1994	12.745%	15.084%	10.672%						
1995	12.892%	15.440%	10.654%						
1996	13.186%	15.530%	11.114%						
1997	13.533%	15.901%	11.426%						
1998	13.519%	15.486%	11.777%						
1999	13.246%	15.104%	11.621%						
2000	11.441%	12.644%	10.393%						
2001	13.104%	14.590%	11.788%						
2002	13.923%	15.625%	12.413%						
2003	15.607%	17.887%	13.561%						
2004	15.969%	18.171%	13.997%						
2005	16.666%	19.093%	14.505%						
2006	17.739%	20.249%	15.522%						
2007	18.192%	20.732%	15.920%						
2008	19.157%	21.826%	16.798%						
2009	18.836%	21.125%	16.760%						
2010	19.070%	21.682%	16.689%						

Year	Health								
	Personal Development, Health and Physical Education								
	Total	Male	Female						
2011	18.642%	21.226%	16.259%						
2012	17.882%	20.636%	15.342%						
2013	17.998%	20.607%	15.563%						
2014	18.654%	20.871%	16.583%						

Year	Languages Other Than English								
	French			German			Italian		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	2.326%	1.149%	3.391%	1.438%	0.833%	1.986%	1.156%	0.660%	1.606%
1993	2.376%	1.155%	3.474%	1.431%	0.831%	1.971%	1.152%	0.604%	1.645%
1994	2.538%	1.259%	3.672%	1.538%	0.945%	2.063%	1.245%	0.730%	1.701%
1995	2.617%	1.311%	3.764%	1.614%	0.955%	2.193%	1.308%	0.793%	1.760%
1996	2.466%	1.234%	3.556%	1.558%	0.941%	2.104%	1.212%	0.710%	1.657%
1997	2.303%	1.158%	3.323%	1.565%	1.009%	2.059%	1.203%	0.709%	1.642%
1998	2.393%	1.205%	3.445%	1.582%	0.974%	2.119%	1.118%	0.646%	1.535%
1999	2.219%	1.105%	3.194%	1.470%	0.921%	1.949%	1.001%	0.606%	1.345%
2000	2.306%	1.198%	3.272%	1.497%	0.997%	1.932%	1.034%	0.617%	1.397%
2001	2.279%	1.070%	3.350%	1.465%	0.921%	1.947%	1.060%	0.610%	1.459%
2002	2.177%	1.101%	3.132%	1.378%	0.886%	1.814%	1.111%	0.615%	1.551%
2003	2.271%	1.144%	3.281%	1.331%	0.899%	1.720%	1.174%	0.685%	1.612%
2004	2.373%	1.253%	3.375%	1.346%	0.925%	1.724%	1.166%	0.672%	1.608%
2005	2.362%	1.273%	3.332%	1.307%	0.965%	1.612%	1.156%	0.680%	1.579%
2006	2.558%	1.399%	3.582%	1.239%	0.878%	1.557%	1.292%	0.723%	1.794%
2007	2.581%	1.404%	3.634%	1.225%	0.937%	1.482%	1.216%	0.666%	1.708%
2008	2.585%	1.408%	3.625%	1.144%	0.873%	1.383%	1.102%	0.662%	1.490%
2009	2.476%	1.510%	3.352%	1.009%	0.758%	1.237%	1.108%	0.644%	1.529%
2010	2.540%	1.443%	3.540%	0.974%	0.715%	1.210%	1.067%	0.641%	1.454%
2011	2.481%	1.457%	3.424%	0.922%	0.735%	1.095%	1.056%	0.642%	1.437%

Year	Languages Other Than English								
	French			German			Italian		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2012	2.655%	1.496%	3.724%	0.939%	0.736%	1.127%	1.121%	0.698%	1.512%
2013	2.564%	1.418%	3.634%	0.876%	0.691%	1.048%	1.092%	0.708%	1.450%
2014	2.461%	1.352%	3.497%	0.936%	0.708%	1.148%	0.995%	0.608%	1.355%

Year	Languages Other Than English								
	Spanish			Japanese			Chinese		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	0.346%	0.302%	0.386%	2.043%	1.112%	2.886%	0.906%	0.898%	0.914%
1993	0.403%	0.344%	0.455%	2.403%	1.375%	3.327%	1.228%	1.250%	1.207%
1994	0.459%	0.398%	0.512%	3.131%	1.695%	4.405%	1.501%	1.600%	1.414%
1995	0.444%	0.344%	0.533%	3.065%	1.808%	4.168%	1.490%	1.644%	1.355%
1996	0.444%	0.354%	0.524%	3.132%	1.724%	4.376%	1.375%	1.447%	1.311%
1997	0.419%	0.324%	0.503%	3.029%	1.628%	4.276%	1.428%	1.494%	1.370%
1998	0.406%	0.318%	0.485%	3.055%	1.769%	4.194%	1.360%	1.412%	1.315%
1999	0.354%	0.251%	0.444%	2.755%	1.613%	3.754%	1.203%	1.234%	1.175%
2000	0.340%	0.268%	0.403%	2.765%	1.613%	3.769%	1.387%	1.456%	1.327%
2001	0.381%	0.291%	0.460%	2.694%	1.754%	3.527%	1.894%	1.881%	1.904%
2002	0.390%	0.298%	0.473%	2.662%	1.650%	3.561%	2.176%	2.236%	2.123%
2003	0.415%	0.336%	0.485%	2.548%	1.739%	3.274%	2.652%	2.734%	2.579%
2004	0.432%	0.315%	0.537%	2.620%	1.814%	3.340%	3.056%	3.201%	2.925%
2005	0.430%	0.294%	0.551%	2.587%	1.815%	3.275%	2.831%	2.937%	2.737%
2006	0.433%	0.339%	0.517%	2.562%	1.988%	3.069%	2.677%	2.772%	2.592%
2007	0.457%	0.331%	0.569%	2.451%	1.861%	2.979%	2.638%	2.690%	2.592%
2008	0.473%	0.338%	0.592%	2.462%	1.789%	3.056%	2.652%	2.716%	2.595%
2009	0.440%	0.330%	0.540%	2.436%	1.822%	2.992%	2.931%	2.957%	2.908%
2010	0.481%	0.342%	0.607%	2.357%	1.661%	2.991%	2.685%	2.698%	2.673%
2011	0.454%	0.359%	0.541%	2.242%	1.736%	2.708%	2.239%	2.216%	2.259%

Year	Languages Other Than English								
	Spanish			Japanese			Chinese		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2012	0.530%	0.389%	0.660%	2.310%	1.807%	2.774%	2.334%	2.381%	2.290%
2013	0.479%	0.321%	0.626%	2.139%	1.616%	2.627%	2.301%	2.253%	2.345%
2014	0.530%	0.370%	0.679%	2.151%	1.646%	2.622%	2.397%	2.310%	2.479%

Year	Vocational Education and Training								
	Hospitality			Business Services			Retail Services		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1992	-	-	-	-	-	-	-	-	-
1993	0.041%	0.020%	0.060%	-	-	-	0.010%	0.006%	0.015%
1994	0.146%	0.077%	0.207%	-	-	-	0.080%	0.066%	0.092%
1995	0.363%	0.242%	0.468%	-	-	-	0.174%	0.167%	0.179%
1996	0.982%	0.608%	1.312%	-	-	-	0.183%	0.160%	0.203%
1997	1.415%	0.915%	1.860%	-	-	-	0.161%	0.124%	0.193%
1998	3.329%	2.136%	4.384%	0.155%	0.097%	0.206%	0.244%	0.195%	0.287%
1999	4.367%	3.017%	5.548%	0.139%	0.089%	0.182%	0.305%	0.273%	0.332%
2000	4.719%	3.006%	6.212%	0.518%	0.233%	0.766%	0.259%	0.235%	0.279%
2001	6.872%	4.039%	9.382%	1.932%	0.731%	2.996%	0.950%	0.741%	1.135%
2002	7.513%	4.593%	10.106%	2.091%	0.699%	3.327%	1.110%	0.815%	1.371%
2003	7.345%	4.544%	9.857%	2.022%	0.845%	3.078%	1.206%	0.874%	1.504%
2004	7.410%	4.638%	9.893%	2.302%	1.083%	3.394%	1.378%	0.930%	1.780%
2005	7.827%	5.075%	10.276%	2.457%	1.295%	3.492%	1.636%	1.129%	2.088%
2006	7.868%	5.285%	10.148%	2.841%	1.667%	3.877%	2.395%	1.381%	3.291%
2007	6.556%	4.406%	8.479%	2.712%	1.662%	3.650%	2.535%	1.426%	3.528%
2008	6.354%	4.301%	8.168%	2.271%	1.282%	3.146%	2.783%	1.632%	3.799%
2009	5.819%	3.929%	7.533%	2.190%	1.325%	2.974%	1.950%	0.986%	2.825%
2010	5.127%	3.442%	6.663%	1.925%	1.142%	2.639%	2.039%	0.924%	3.056%
2011	6.239%	4.200%	8.118%	2.430%	1.833%	2.981%	2.033%	0.841%	3.132%

Year	Vocational Education and Training								
	Hospitality			Business Services			Retail Services		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
2012	5.941%	3.764%	7.948%	2.282%	1.871%	2.662%	0.884%	0.585%	1.160%
2013	5.137%	3.316%	6.836%	1.464%	0.915%	1.977%	1.195%	0.754%	1.607%
2014	4.798%	2.868%	6.600%	1.102%	0.633%	1.541%	0.864%	0.549%	1.159%

Year	Vocational Education and Training								
	Construction			Information Technology					
	Total	Male	Female	Total	Male	Female			
1992	-	-	-	-	-	-			
1993	-	-	-	-	-	-			
1994	-	-	-	-	-	-			
1995	-	-	-	-	-	-			
1996	-	-	-	-	-	-			
1997	-	-	-	-	-	-			
1998	0.403%	0.835%	0.020%	-	-	-			
1999	0.488%	1.019%	0.023%	1.183%	1.329%	1.053%			
2000	0.688%	1.444%	0.029%	1.897%	2.232%	1.603%			
2001	1.607%	3.375%	0.040%	2.455%	3.014%	1.967%			
2002	1.676%	3.518%	0.041%	5.284%	6.735%	3.998%			
2003	1.566%	3.262%	0.046%	5.885%	7.925%	4.074%			
2004	1.669%	3.483%	0.045%	5.718%	7.993%	3.676%			
2005	1.879%	3.905%	0.075%	4.933%	6.925%	3.149%			
2006	1.631%	3.420%	0.051%	4.577%	6.505%	2.860%			
2007	1.819%	3.804%	0.044%	3.652%	5.383%	2.124%			
2008	2.055%	4.290%	0.080%	3.453%	5.181%	1.908%			
2009	2.324%	4.803%	0.075%	3.253%	4.905%	1.792%			
2010	2.036%	4.189%	0.074%	2.968%	4.417%	1.654%			
2011	2.419%	4.880%	0.151%	2.575%	3.843%	1.419%			

Year	Vocational Education and Training								
	Construction			Information Technology					
	Total	Male	Female	Total	Male	Female			
2012	1.901%	3.851%	0.102%	2.207%	3.330%	1.172%			
2013	2.089%	4.203%	0.115%	1.800%	2.637%	1.028%			
2014	1.798%	3.600%	0.116%	1.638%	2.401%	0.926%			

Appendix B: The Implications of the continuing decline of science enrolments in Australian high-schools: A case study.

Introduction

In Chapter 3 I demonstrated that student participation rates in science and mathematics courses across Australia were continuing to decline although at a much slower rate of change than in earlier years. In order to investigate the agreement of national enrolment trends with local, school-level trends I carried out a small scale case study involving Year 10 students in a Sydney based, co-educational K-12 school. The insights gained from this case study are particularly pertinent to understanding research questions RQ3, RQ5 and RQ8. The choice of a single school case study allows for an understanding of the nature of participation rate changes in science and mathematics courses while factoring out wider influences such as curriculum offerings and school ethos.

The article presented in this chapter originally took the form of a poster presentation (Kennedy, 2014) and demonstrates that the local explanations can be drawn out from a comparison with high-level national-scale data. This approach essentially asks the questions, “how similar are the patterns in participation rates in my school to those seen nationally?”, and, “what makes my school different?”

The article first outlines the nature of the observed declines in science and mathematics participation rates and places these into the context of long-term—20 year—and short-term—5 year—changes. The article then examines the observed trends through the eyes of an educational practitioner in the classroom and compares the school’s enrolment trends for science courses with the national picture in particular looking for differences in the scale and rate of the changes.

The article then discusses the findings of a small scale survey, based on the work of Schreiner and Louis (2006), in an attempt to understand some of the key blockers to student engagement in the classroom. From the survey findings and students’ verbatim commentaries, I identified the constructs of engagement and relevance as being particularly key to understanding students’ own explanations for their intentions to continue to study science into post-compulsory education or not.

Proceedings Article 1

The content of this article was originally submitted to the Teachers' Guild of New South Wales' Annual Poster Presentation and Lecture Evening in the form of a poster (Kennedy, 2014) and was awarded the Helen Hughes Research Award. This article was written following the content of the original poster and originally published in the biannual Proceedings of the Guild available at http://www.teachersguild.nsw.edu.au/proceedings.

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The Implications of the continuing decline of science enrolments in Australian high-schools.

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Is there a crisis in Australian science and mathematics education? Declining enrolments in upper secondary science and mathematics courses have gained much attention from the media, politicians and high profile scientists over the last few years, yet there is still no consensus amongst stakeholders about either the nature or magnitude of the changes. In this paper I present the raw enrolment data collected from the education departments of each of the Australian states and territories from 1992 to 2012 and the analysed trends for biology, chemistry, physics, two composite subject groups (earth science and multidisciplinary sciences), as well as entry, intermediate and advanced mathematics. The results of these analyses are presented and discussed in terms of participation rates, raw enrolments and gender balance. A number of hypotheses are discussed to explain these observed declines, and I propose that the broadening of curriculum offerings, further driven by students' self-perception of ability and perceptions of subject difficulty and usefulness, are the most likely causes of the changes in participation. The results of an engagement and intentions survey of Year 10 students at St Andrew's Cathedral School are presented alongside these national enrolment trends in order to begin to offer insight for the trends at school level and the implications for student engagement and curriculum design in upper secondary school are discussed.

Introduction

There has been significant media coverage of the apparent decline of Year 12 Science and Mathematics enrolments over the last few years, though the evidence presented has often appeared confusing and at times even contradictory. A study commissioned by Australia's Chief Scientist concluded that all the main high school sciences were experiencing continuing and dramatic declines (Goodrum, Druhan, & Abbs, 2011). However, the scale of those reported declines has since been questioned (Ferrari, 2011) leading to confusion over the actual figures.

At the senior high school level a number of historic reports (e.g., Ainley, Kos, & Nicholas, 2008; Dekkers & de Laeter, 2001; Hackling, Goodrum, & Rennie, 2001; Hassan & Treagust, 2003) point to either a decline in science education enrolments in Australia or, at best, zero growth over the long term. Studies into the state of mathematics (Barrington, 2006; Mack & Walsh, 2013; Thomson, 2009) have reported similar levels of decline in participation.

The trends reported in Australia have been echoed to various extents in a number of countries across the globe including England and Wales (Smith, 2011), France (Charbonnier & Vayssettes, 2009), India (Garg & Gutpa, 2003), Israel (Trumper, 2006), and Japan (Schleicher & Ikeda, 2009) thus suggesting that the causes of the changes may go beyond national and cultural borders.

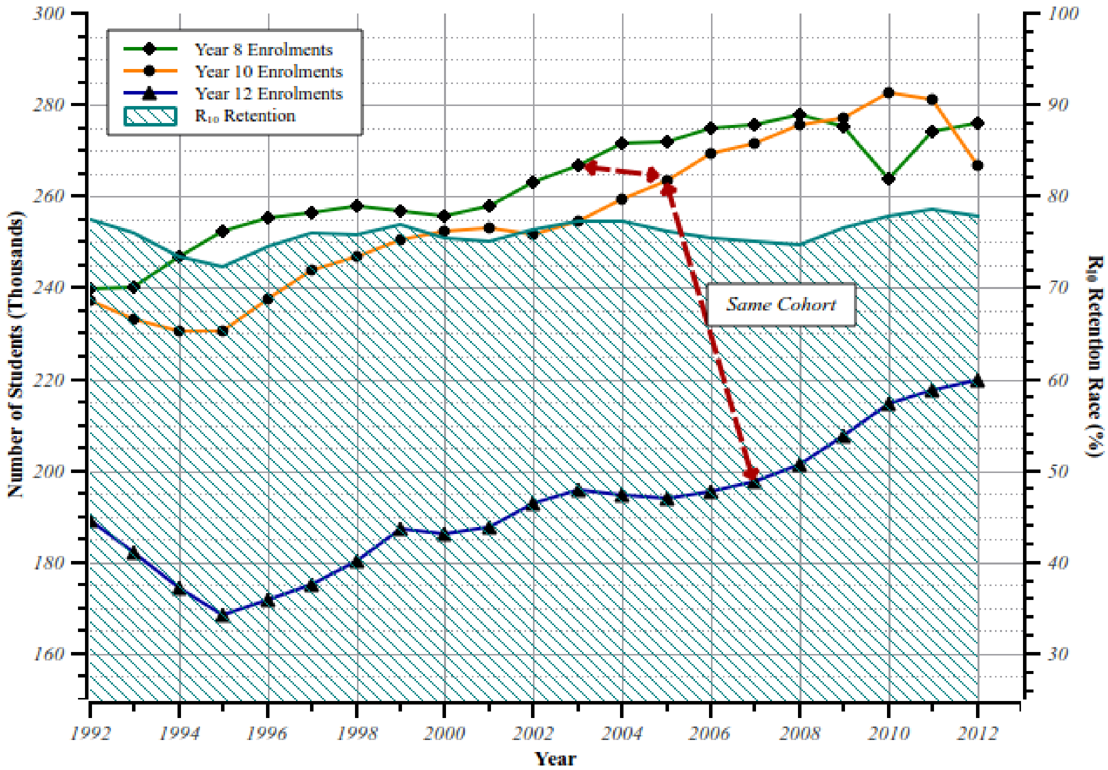


Figure B.1. Overall national enrolment numbers (left hand axis) for Year 8, Year 10 and Year 12 with retention rate (right hand axis) from 1992 to 2012. (From: Kennedy et al., 2014)

A recent study by Kennedy, Lyons and Quinn (2014) has shown that participation rates across the range of science subjects offered in Year 12 by the eight states and territories has continued to decline (figure B.2) throughout the period 1992-2012 even though total Year 12 enrolments have risen from 190,000 to 220,000 students in the same period. This same study also showed that participation rates in intermediate and advanced mathematics courses also declined over a similar period.

The work of Dekkers and de Laeter (2001) showed that the retention rate from Year 10 to Year 12 peaked and stabilised at around 75% in 1992. This year was therefore chosen as a baseline from which to make valid comparisons without the effect of an increasing number of Year 12 students masking any changes. The year 1994 was selected as the base-level for mathematics enrolments (in keeping with Barrington and Brown (2005)) since categorising courses based on common content prior to this is unreliable due primarily to curriculum design in Victoria.

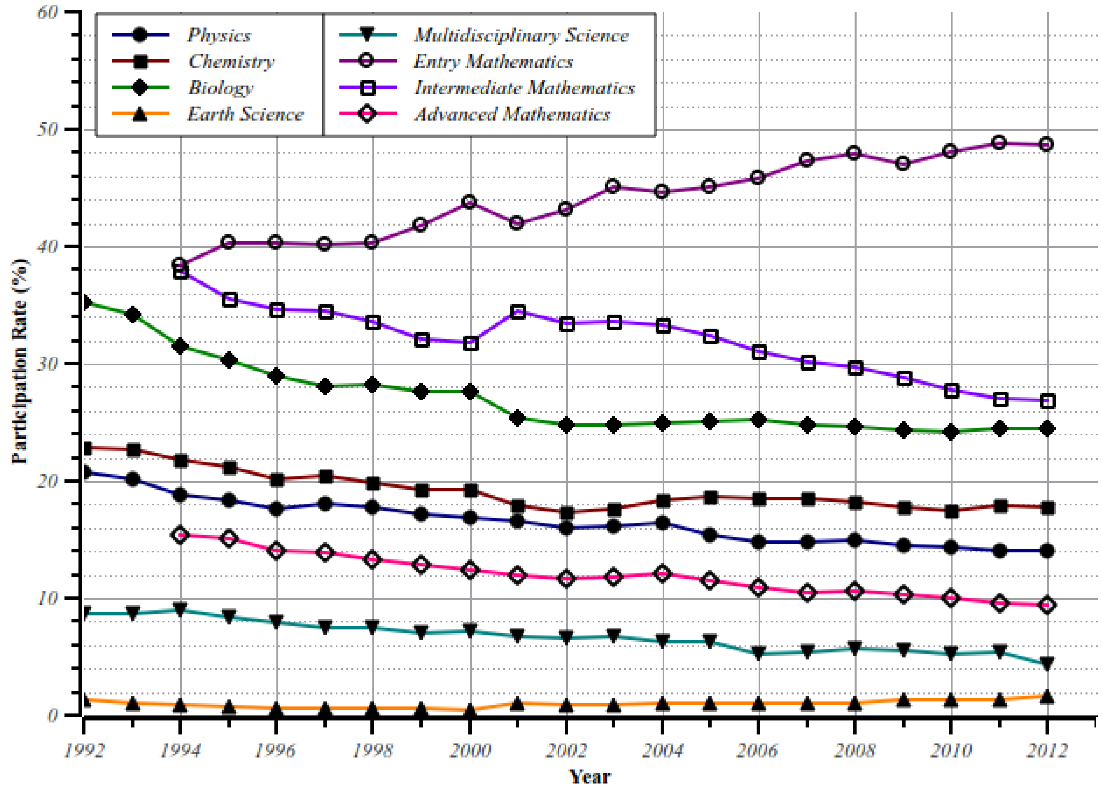


Figure B.2. Participation rates for science and mathematics subjects, 1992-2012 (From: Kennedy et al., 2014)

Figure B.1 shows that the total number of students in Year 12 increased by around 16% from 1992 to 2012 while Year 10 to Year 12 retention rates remained relatively stable at around 75%. As is shown in figure B.2 the participation rates for most science and mathematics subjects fell (biology (-10%), chemistry (-5%), physics (-7%), multidisciplinary science (-5%), intermediate mathematics (-11%), advanced mathematics (-7%)) in the same period. However, there were increased participation rates in earth sciences (+0.3%) and entry mathematics (+11%). Earth sciences includes enrolments for the group of courses geology, environmental science, earth and environmental science, and similar courses. Entry mathematics refers to a group of mathematics courses that do not generally include calculus but which can contribute the student's calculated Australian Tertiary Admission Rank (ATAR). In each case the greatest rates of change occurred prior to 2001 and have been slower and steadier since.

Implications for schools

As a science classroom practitioner, the trends presented in Kennedy et al. (2014) are a serious cause for concern. Science courses in Year 12 have the potential to build significant skills in students which are relevant for business and society in general. These skills include critical thinking, creative problem solving and critical analysis of presented data and information.

In order to compare the St Andrew's Cathedral School context with the national data, Year 12 examination enrolment data were extracted from the NSW Board of Studies Results Analysis Package (RAP) for the period 2002 to 2012. These were then combined with school records of total enrolments to produce participation rates along similar lines to those previously presented. St Andrew's Cathedral School has offered Year 12 Senior Science (multidisciplinary science) sporadically over this period and so participation rates were not calculated for this course. The findings are shown in figure B.3.

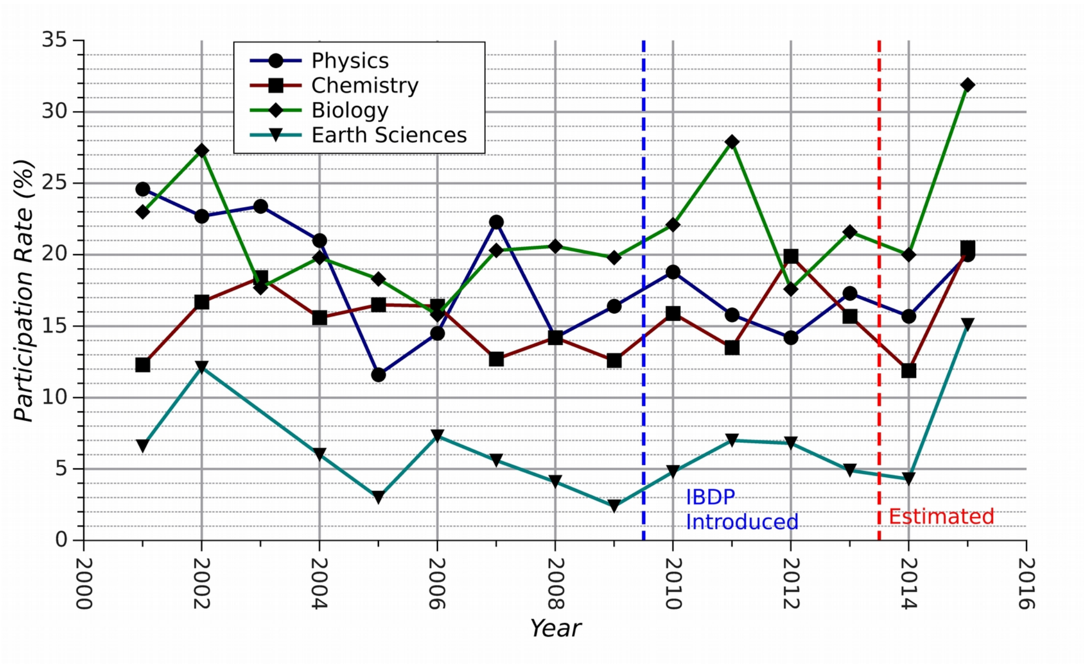


Figure B.3. Science Participation Rates for St Andrew's Cathedral School 2002-2012

Observations

The science trends at St Andrew's Cathedral School show some similarities to the national trends when accounting for volatility. The volatility in the observed trends is due to the significantly small cohort numbers used in calculating the participation rates (total Year 12 enrolments averaged)

Chemistry shows a similar, almost stationary trend, although the school shows a slightly lower participation rate (around 16%). Biology and Physics show slightly steeper declines than the national trends. However, Biology, has been consistently lower than national participation rates (18% in 2012), while Physics has been consistently higher (14% in 2012). Earth Sciences nationally grew slightly while St Andrew's Cathedral School enrolments have fallen significantly. However, the school's participation rates (7% in 2012) have been consistently and significantly larger than the national trends.

Discussion

As the trends in the science subjects' participation rates at St Andrew's Cathedral School were showing similar trends to the national data, albeit at a different magnitude, a reflective review was carried out with Year 10 students to try to ascertain why they did and did not choose to study science beyond Year 10. A number of researchers (e.g., Hackling et al., 2001; Lyons & Quinn, 2010; Parn, 2006)have identified the concept of student engagement as being key in understanding their future patterns of enrolment.

An online survey was developed based on the work of Schreiner and Louis (2006) to assess student engagement with science and enrolment intentions for next year and was delivered to Year 10 just prior to the end of Semester 1 2014. The survey was implemented using an online survey provider and in addition to the seven-point likert scale items of the original survey, a number of open responses were included to allow students to explain any of their previous answers. Students were also asked to indicate the Year 11 science subjects, or no science, that they were considering enrolling in for the following year.

The response rate was 57% (n=73; 59% male: 54% female) and represented the full range of student ability in science. Student responses (figure B.4) to engagement covered the full range of the scale with the mean response being 4.67 (neutral-slightly engaged). Responses show significant skew towards the “engaged pole” yet there is significant weighting in the neutral region. This finding raises the question “how can we better engage our Year 10 students?”

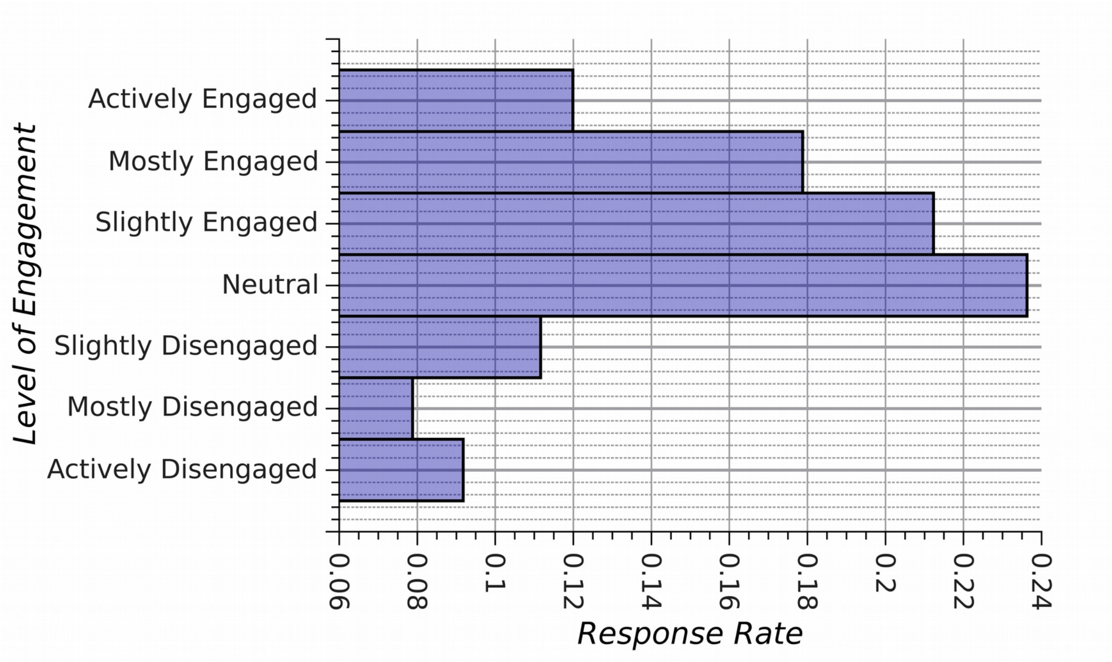


Figure B.4. Levels of Year 10 student engagement in science classes.

Most students chose not to elaborate on their answers. However, of those that did, student explanations for their engagement responses tended to focus more on the negative aspects of class. Explanations included:

"I quite like science but I don't think some of the things we have learned are explained very well."

"[I] find some subjects uninteresting due to having previously learned about them at a higher level."

"I try and learn in class but all my teacher does is spend a whole lesson talking about one thing without giving anyone else a chance to talk."

"My class is to loud and rowdy. I find it hard to concentrate and participate in class discussion."

"[Science] is not taught in a way that interests or engages me"

The predicted participation rates (figure B.5) are particularly interesting. If these were to translate into actual enrolments, then all four science strands would see significant jumps in 2016. Biology would increase to 53%, Physics to 47%, Chemistry to 47%, and Earth Sciences to 26%. This would continue the significant gains seen in enrolments for 2015. This is likely to be a direct impact of a recent refocussing of learning towards inquiry based science and away from the teaching of science facts. As a department it is important that we now reflect on our recent practice and continue to do what we have been doing.

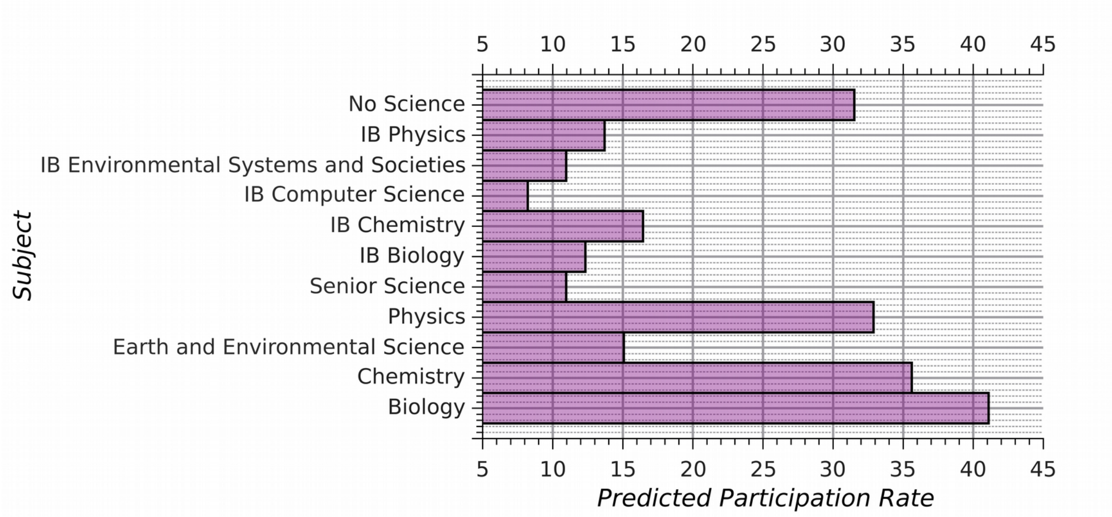


Figure B.5. Predicted Year 11 participation rates for 2015 based on student enrolment considerations in Year 10.

Student explanations for selecting science tended to be positive in nature and focus on career value or intrinsic interest. They included:

“I really enjoy learning about the human body and it's processes. I also want to do something in medicine after school.”

“Whatever course is most relevant to the course I want to do at Uni.”

“It is more relevant to the degree that I want to do.”

“Always been interested in this area; current science doesn't talk about these areas”

“I want to be a vet when I grow up”

It is worth noting that students' explanations relating to engagement tended to place the ownership for that lack of engagement on to the teacher and the other members of the class. However, students seemed to assume direct ownership for the relevance of the subject to their future needs. Interestingly, these explanations clearly emphasise that students do not generally find science “too hard”. The primary importance of the teacher-student relationship, especially with regards to engagement, is evident in these explanations as well as the need for the subject to be perceived as being strategically valuable for their future career intentions or long standing interests.

Conclusions & Recommendations

It is clear from this brief study that key to maintaining student enrolments in the disciplines of science in the senior years of school are the factors of engagement and relevance. Students must be engaged by their teachers early on in their school science careers and they must be shown the relevance of school science to many future careers, not just those directly related to the science field. This needs to be the responsibility of schools, teachers and students themselves if Australia is to continue to produce scientists of world renown. As the Chief Scientist of Australia stated, “The reality is that we can't relax. We can't be complacent There can be no sense of entitlement. We must understand that we will get the future we earn.” (Office of the Chief Scientist, 2013)

Implications of the continuing decline of Science enrolments in Australian high schools

John Kennedy
University of New England, Armidale and St Andrew's Cathedral School, Sydney.

Is there a crisis in School Science?

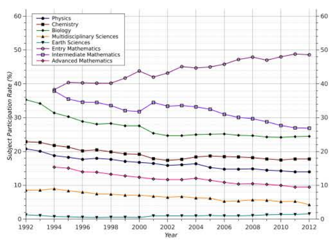
The significant media coverage of the declining Year 12 Science and Mathematics enrolments over the last few years appears clear cut, but the evidence has been confusing and even contradictory. A study commissioned by Australia's Chief Scientist concluded that all the main high school sciences were experiencing continued dramatic declines (Goodrum, Druhan, & Abbs, 2011). A number of reports (e.g. Ainley, Kos, & Nicholas, 2008; Dekkers & de Laeter, 2001; Hackling, Goodrum, & Rennie, 2001; Hassan & Treagust, 2003) point to either a gradual decline in science education enrolments in Australia or, at best, zero growth over the long term. Studies into the state of mathematics (Barrington, 2006; Thomson, 2009) have reported similar levels of decline in participation. This study finally sets the story straight.

The Australian situation

Methods, Definitions and Constraints

- State and territory curriculum authorities publish raw enrolment data annually for every Year 12 course; the national statistics presented in these graphs were **compiled** from these individual raw data sets.
- The year **1992** was selected as a **science base-level** as the work of Dekkers and de Laeter (2001) had already shown this as the year in which participation rates peaked and retention rates from Year 10 to Year 12 stabilised at around 75%.
- The year **1994** was selected as the **base-level** for **mathematics** enrolments (in keeping with Barrington and Brown(2005)) since categorising courses prior to this is unreliable due mainly to course designations in Victoria.
- Each of the different state and territory boards offers science subjects under slightly different titles:
  - enrolments for **biology** also include enrolments for human biology.
  - enrolments for geology, environmental science, and earth and environmental science are grouped under the term **earth sciences**.
  - less specialised science courses such as senior science in New South Wales, integrated science in Western Australia and science21 in Queensland are grouped as **multidisciplinary science.**
- To allow for valid comparisons between states and over time **only** enrolments in the **highest level** course available are included.
- **Participation rate** is defined as being the proportion of the **total** Year 12 cohort enrolled in a particular course.
- Science and mathematics subjects are often reported as being gender biased in their enrolments (Fullarton, Walker, Ainley, & Hillman, 2003). The **sex ratio** is presented as the female proportion of **total** enrolments in a particular course.
- Year 12 students can and often do enrol in multiple science courses; however, because of the way enrolments are reported by the states and territories it is not possible to determine reliably the number of students enrolled in multiple courses.

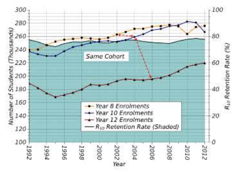
Findings



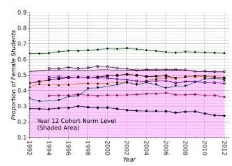
◀ **Figure 1** *(from Kennedy, Lyons and Quinn (2014))* The participation rates for **almost all** science and mathematics subjects as a proportion of the overall year 12 cohort size have been declining over the period 1992 to 2012. The **exceptions** being entry mathematics and earth sciences.

It is interesting to note that **much of the declines happened prior to 2001** before the major curriculum changes of the early 2000's.

Post-2004, it is also interesting to note the **parallel declines of advanced mathematics** and **physics** as well as the virtual **stagnation** of **chemistry** and **biology**



▲ **Figure 2** The trends in overall national **enrolment numbers** (left hand axis) for Year 8, Year 10 and Year 12 have been steadily **rising** from 1992 to 2012, while the **retention rates** (shaded) from Year 10 into Year 12 (right hand axis) have been fairly **stable**. *(from Kennedy, Lyons and Quinn (2014))*



▲ **Figure 3** Subject sex ratios for science and mathematics courses from 1992-2012 with the overall sex ratio of the Year 12 cohort shown shaded. *(from Kennedy, Lyons and Quinn (2014))*

Note that **biology** has been **consistently female biased** and **physics** and **advanced mathematics** have been **consistently male biased**. Most other courses have been historically male biased but have tended closer to equality over time.

Summary of National Trends

- The total number of students in Year 12 **increased** by around 16% from 1992 to 2012.
- The participation rates for **most science** and mathematics subjects **fell** (biology (-10%), chemistry (-5%), physics (-7%), multidisciplinary science (-5%), intermediate mathematics (-11%), advanced mathematics (-7%)) in the same period.
- There were **increased participation rates** in earth sciences (+0.3%) and entry mathematics (+11%).
- In each case the **greatest rates of change** occurred **prior to 2001** and have been slower and steadier since.

The St Andrew's situation

Research Questions

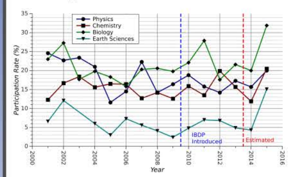
- Do the trends in science at St Andrew's Cathedral School reflect those of the rest of the country?
- How do students perceive science in Years 11 and 12? Are they intending to enrol on a science course?
- What can we do in our Year 10 classrooms to promote the uptake of science in Years 11 and 12?

Methods

Existing literature (e.g. Lyons and Quinn, 2010; Osborne et al., 2003) indicates that among a number of factors affecting student enrolments there are two factors that are particularly important; namely **student engagement** with the subject in the years before stage 6, and student's perceptions of "**value**" for a particular course.

An online survey (using sogosurvey.com) was developed based on the work of Schreiner and Louis (2006) to assess **current levels** of student engagement with science together with their **enrolment intentions** for Year 11 2015. This was delivered to all of Year 10 just prior to the end of Semester 1 2014.

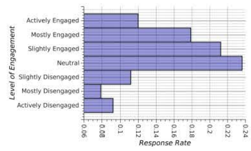
Findings

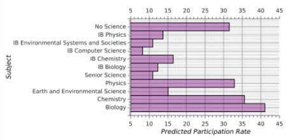


◀ **Figure 4** The science trends at SACS show **some similarities** to the national trends when accounting for the volatility.

- Chemistry shows a similar, almost stationary trend, although the participation rate isslightly lower .
- Biology and Physics show slightly steeper declines.
  - Biology has had consistently lower participation rates
  - Physics has had consistently higher rates
- Earth Sciences grew nationally but SACS enrolments have fallen significantly.
  - But SACS participation rates have been consistently and significantly larger than the national trends.

Figure 5 ▶
- The survey **response rate** was 57% (n=73; 59% male: 54% female).
- Student responses covered the full range of the scale from 1 (strongly disengaged) to 7 (strongly engaged).
- The **mean response** was 4.67 (neutral-slightly engaged).
  - Responses show significant **skew** towards the "engaged pole"
  - But there is significant **kurtosis** towards the central region.





◀ **Figure 6** The enrolment intentions of Year 10 give these **predicted participation rates**.

- If these predicted participation rates were to translate into actual enrolments, then all four science strands would see significant jumps in 2016.
  - Biology rises to 53%,
  - Physics rises to 47%,
  - Chemistry rises to 47%,
  - Earth Sciences rises to 26%.
- This would continue the significant gains seen in enrolments for 2015.

Student Explanations

- Most students chose not to elaborate on their answers, but of those that did:
  - student explanations for their engagement responses tended to focus more on the negative responses.
  - student explanations for future enrolments tended to focus on value for career and long-standing interest.

"There's so much to say about what I enjoy in science."

"I love science."

"I quite like science but I don't think some of the things we have learned are explained very well."

"[I] find some subjects uninteresting due to having previously learned about them at a higher level."

"I try and learn in class but all my teacher does is spend a whole lesson talking about one thing without giving anyone else a chance to talk."

"My class is to loud and rowdy. I find it hard to concentrate and participate in class discussion."

"I get bored in science class"

"[Science] is not taught in a way that interests or engages me"

"I only enjoy learning biology and doing pracs."

"I really enjoy learning about the human body and it's processes. I also want to do something in medicine after school."

"Whatever course is most relevant to the course I want to do at Uni."

"It is more relevant to the degree that I want to do."

"Always been interested in this area: current science doesn't talk about these areas"

"I want to be a vet when I grow up"

These explanations emphasise:
- that students do **not** generally find science "**too hard**",
- show the importance of **engaging** students in the classroom **early on.**
- the importance of the **teacher-student relationship**
- that students select subjects based on their **strategic value** to their **future career** intentions or long standing **interests**.

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Acknowledgements

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Australian Science Enrolment Project

ST ANDREW'S CATHEDRAL SCHOOL
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Appendix C: Original Appendices to The School Science Attitude Survey: A new instrument for measuring attitudes towards school science

This appendix contains two tables that were originally included as Appendix 1 and Appendix 2 of the article presented in this thesis as Chapter 6.

Appendix C-1: Listing of the wordings used for the items in the pilot survey.

Listing of the wordings used for the items in the pilot survey. The original instruments: TOSRA (Fraser, 1982), PCSC (Wilson, 2009), ROSE (Schreiner & Sjøberg, 2004) and VASS (Halloun, 2001), with the original item number in parenthesis, are indicated; items marked – were developed specifically for this pilot survey. The listing also notes the intended Attitudinal Factor: enjoyableness (E), difficulty (D), self-efficacy (S), relevance (R), usefulness (U) and intentions (I) and the measurement method: Likert-type visual analogue scale (VSS-LT), semantic differential visual analogue scale (VSS-SD) or traditional five-point discreet Likert-type scales (D-LT). Reverse keyed items are indicated with *. Finally, the item groupings identified by two post-hoc focus groups are identified with lowercase letters a-e (year 7) and Roman numerals i-viii (year 10) (refer to table 2 for grouping descriptions).

Item #	Attitudinal Factor	Item Wording	Measurement method	Original Tool	Year 7 Group	Year 10 Group
1	E	I find *Science* to be very enjoyable.	VSS-LT	–	c	ii
2	E	Science lessons are fun	VSS-LT	TOSRA (5)	c	ii
3	E	Science lessons bore me	VSS-LT*	TOSRA (26)	c	vi
4	E	Science is one of the most interesting school subjects	VSS-LT	TOSRA (33)	c	ii
5	E	Science lessons are a waste of time	VSS-LT*	TOSRA (40)	c	vi
6	D	I am often confused by the content of science classes	VSS-LT	PCSC (1)	e	v
7	D	It is difficult for me to complete the assignments for science class	VSS-LT	PCSC (7)	e	v
8	D	I struggle with completing the assignments for science class	VSS-LT	PCSC (9)	e	v
9	D	I struggle with completing the out of class assignments for science class	VSS-LT	PCSC (15)	e	v
10	D	I find science a difficult subject	VSS-LT	–	e	v
11	D	Learning new things is difficult for me	VSS-LT*	PCSC (10)	e	v
12	S	I do well in science	VSS-LT	PCSC (8)	d	iv
13	S	I am a good student	VSS-LT	PCSC (3)	d	iv

Item #	Attitudinal Factor	Item Wording	Measurement method	Original Tool	Year 7 Group	Year 10 Group
14	S	I am good at learning new things in science	VSS-LT	PCSC (12)	d	iv
15	S	I think I am very good at science:	VSS-LT	–	d	iv
16	S	I think that I am much better than my friends at science	VSS-LT	–	d	iv
17	R	Money spent on science is well worth spending.	VSS-LT	TOSRA (1)	c	i
18	R	Public money spent on science in the last few years has been used wisely.	VSS-LT	TOSRA (15)	c	i
19	R	Scientific discoveries are doing more harm than good	VSS-LT*	TOSRA (22)	c	vii
20	R	The government should spend more money on science	VSS-LT	TOSRA (29)	a	i
21	R	I want to learn about how crude oil is converted to other materials like plastics and textiles	VSS-LT	ROSE (C1)	a	iii
22	R	I want to learn about how to improve the harvest in gardens and farms	VSS-LT	ROSE (E17)	a	iii
23	R	I want to learn about how different sorts of food are produced, conserved and stored.	VSS-LT	ROSE (E22)	a	iii
24	R	I want to learn about animals in my area	VSS-LT	ROSE (E24)	a	iii
25	R	I want to learn about plants in my area	VSS-LT	ROSE (E25)	a	iii
26	R	The science I learn at school is very relevant to my everyday life	VSS-LT	–	d	viii
27	U	I would dislike being a scientist when I leave school	VSS-LT*	TOSRA (7)	b	vii
28	U	When I leave school, I would like to work with people who make discoveries in science	VSS-LT	TOSRA (14)	b	viii
29	U	I would dislike a job in a science laboratory after I leave school	VSS-LT*	TOSRA (21)	b	vii
30	U	Working in a science laboratory would be an interesting way to learn a living	VSS-LT	TOSRA (28)	b	viii
31	U	The science I learn at school will be very useful for my future career	VSS-LT	–	b	viii
32	I	I am very likely to enrol on a science course in Year 11.	VSS-LT	–	b	viii
33	I	I am very likely to enrol on a physics or chemistry course in Year 11	VSS-LT	–	b	viii
34	I	I am very likely to enrol on a biology or earth science course in Year 11	VSS-LT	–	b	viii
35	E	Studying *science* is for me: an enjoyable experience ; a frustrating experience	VSS-SD*	VASS (28)	c	ii

Item #	Attitudinal Factor	Item Wording	Measurement method	Original Tool	Year 7 Group	Year 10 Group
36	E	I would like to study science in order to satisfy: my own interests ; what certain people expect of me.	VSS-SD*	VASS (43)	b	iii
37	E	I think science is: Boring ; Enjoyable	VSS-SD	–	c	vi
38	E	I would like the materials in my science course to be covered in a way to help me: do well on science exams ; develop my reasoning skills	VSS-SD	VASS (42)	a	viii
39	E	I think Science is: Unsatisfying ; Satisfying	VSS-SD	–	c	vi
40	S	For me, science is: Difficult ; Easy	VSS-SD	–	d	iv
41	S	My ability in science is: Weak ; Strong	VSS-SD	–	d	iv
42	D	I think that science is: Difficult ; Easy	VSS-SD	–	e	v
43	D	I think that science is: Challenging ; Simple	VSS-SD	–	e	v
44	U	For my future career, science will be: Optional ; Required	VSS-SD	–	b	vii
45	U	For my planned career, knowledge of school science will be: Worthless ; Required	VSS-SD	–	b	viii
46	R	I think that when properly presented, science courses can be helpful to me: In my everyday life ; If I were to become a scientist	VSS-SD	VASS (40)	a	viii
47	R	I use the things I learn in school science: Almost Never ; Everyday	VSS-SD	–	b	viii
48	R	For my everyday life, I think school science is: irrelevant ; relevant	VSS-SD	–	b	vii
49	I	The likelihood that I will choose a Science course in year 11 is: low ; high	VSS-SD	–	c	vii
50	I	The chances that I will do physics or chemistry in year 11 is: unlikely ; likely	VSS-SD	–	b	viii
51	I	The probability that I will do biology or earth science in year 11 is: improbable ; probable	VSS-SD	–	c	vii
52	E	I really enjoy going to science lessons	D-LT	TOSRA (47)	c	ii
53	E	The material covered in science lessons is uninteresting	D-LT*	TOSRA (54)	e	vi
54	E	I look forward to science lessons	D-LT	TOSRA (61)	c	ii
55	E	I would enjoy school more if there were no science lessons	D-LT*	TOSRA (68)	e	vi

Item #	Attitudinal Factor	Item Wording	Measurement method	Original Tool	Year 7 Group	Year 10 Group
56	D	I am often confused while doing the out of class assignments in science	D-LT	PCSC (6)	e	v
57	D	I find it difficult to understand the assignments for science class	D-LT	PCSC (11)	e	v
58	S	I learn things quickly in science	D-LT	PCSC (14)	d	iv
59	S	I make good grades in science at school	D-LT	PCSC (16)	d	iv
60	R	Science can help to make the world a better place in the future.	D-LT	TOSRA (57)	b	viii
61	R	Money used on scientific projects is wasted	D-LT*	TOSRA (64)	c	vii
62	R	Science helps to make life better	D-LT	TOSRA (43)	b	viii
63	R	I want to learn about electricity and how it is used in the home.	D-LT	ROSE (E27)	a	iii
64	R	I want to learn about how to use and repair everyday electrical and mechanical equipment	D-LT	ROSE (E28)	a	iii
65	R	I want to learn about the risks and benefits of food additives	D-LT	ROSE (E35)	a	iii
66	U	I would like to teach science when I leave school	D-LT	TOSRA (42)	b	viii
67	U	A job as a scientist would be interesting	D-LT	TOSRA (56)	b	viii
68	U	A career in science would be dull and boring	D-LT*	TOSRA (35)	b	vii

Appendix C-2 Listing of the final wording of the School Science Attitudes Survey

Listing of the final wording of the School Science Attitudes Survey with the estimated reliabilities for each item and item grouping. All items are measured using a visual analogue scale from -50 to 50 with either Likert-type (LT) strongly disagree to strongly agree or semantic differential (SD) endpoints. For the latent attitudinal factors, formulae to aid in their calculation are outlined.

Attitudinal Factor		Item Wording	Measurement method
Intentions to enrol in further science	I	I am very likely to enrol on a science course in Year 11.	LT
Enjoyableness of school science	E	I think science is:	SD Boring ; Fun
Perceived difficulty of school science	D	I struggle with completing the assignments for science class	LT
Perception of self-efficacy in school science	S	I think I am very good at science:	LT
Usefulness of science to careers	U		Latent: $\frac{U_S+U_P}{2}$
Usefulness of school science to scientific careers	U_S	A job as a scientist would be interesting	LT
Usefulness of school science to personal career choice	U_P	For my planned career, knowledge of school science will be:	SD Worthless ; Required
Relevance of school science	R		Latent: $\frac{R_S+R_P}{2}$
Relevance of school science to society	R_s	Science helps to make life better	LT

Attitudinal Factor		Item Wording	Measurement method
Personal relevance of school science	R_P		Latent: $\frac{R_{P1}+R_{P2}+R_{P3}}{3}$
What do I want to learn about?	R_{P1}	I want to learn about plants in my area	LT
How applicable is school science to my everyday life?	R_{P2}	For my everyday life, I think school science is:	SD Irrelevant ; Relevant
Biological vs physical science	R_{P3}	I want to learn about electricity and how it is used in the home.	LT