Science and Mathematics Education Centre

Perseverance in Science Education:

A Longitudinal Study on the Academic Journeys of Eight Female Students

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DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any other university.

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number SMEC- 03- 10.

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ABSTRACT

This longitudinal study closely follows the progress of eight female students from secondary school to the end of their first degree, and in some cases the start of their career. The research identifies the factors which are responsible for the students' perseverance in science education.

The research questions addressed in this study are: What are the interests and attitudes of these students towards science education? Is there a relation between the students' success in the school examinations and their choice of a degree? What are the factors which influence these students to persevere and complete their science degrees?

Data were collected from established science attitude and learning environment questionnaires given to 16 participants initially. From this cohort, eight were selected for the study. Scores were calculated and tabulated for initial science interests and attitudes. Year 10 School Certificate results and Year 12 Higher Secondary School Certificate results were used to provide additional initial data.

Questionnaires were given to the students, their teachers and parents. Interviews were conducted at different stages both in person, by telephone and online, to collect data at various stages of the student's academic journey. The individual academic journey of each participant was written as a case study.

When the eight case studies are compared, similarities are indeed more common than differences. Similarities include a positive attitude towards science education at an early age, consistent results with both school external examinations, and strong personal characteristics of each individual student as determining factors for their success. For some students, teachers or friends also played leading roles whereas for others, the home or career motivations were more important.

All the students came from stable homes and their parents were very involved in their education. Some mothers worked outside the home and some did not. Either way the family influence was strong. This stability and security at home resulted in the development of strong confident characters that were further enhanced by teachers, mentors, friends, all acting cohesively to provide a support system. Perseverance in science education for these eight students has been the result of strength of character and individual choices.

ACKNOWLEDGEMENTS

Longitudinal studies are not very common and those researchers who may dare to undertake such studies should be prepared for a longer journey towards the completion of the task. This study took longer than expected and at times looked as if it would never be completed.

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I owe much to my late parents. My father Frank Gunnion, a science teacher himself, encouraged and inspired me to become a Physics teacher and to devote my time to teach science to female students. My mother Molly Almeida always believed that I would one day achieve a doctorate.

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The perseverance of the eight participants towards the completion of their goals is the motto of this study. I thank them for their generosity in sharing their academic journeys in science education.

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CHAPTER 1

INTRODUCTION

"Great works are performed not by strength, but by **perseverance***." Samuel Johnson. (Johnson, 1825, p. 215).*

1.0 Overview

This longitudinal study was designed to follow eight female participants from school to university to determine the factors responsible for their success in the field of science education. This chapter has highlighted the three research objectives of the study and has explained the processes involved with the collection of data to answer these objectives and the research questions related to them. This chapter has also described the research design, the significance of the study and the structure of the thesis.

1.1 Background to the Study

This year the award for the Australian of the Year 2018, presented by the National Australian Day Council, to Professor Michelle Simmons from the University of New South Wales (UNSW), was an achievement for women in science all over the world.[1] Professor Simmons is leading a quantum physics team at the University of New South Wales to build the world's first quantum computer which will revolutionise the future of scientific applications in daily life. She is an excellent modern-day role model for young boys and girls studying science and hoping to have a scientific career. Michelle Simmons encourages students to dream big, challenge themselves and to achieve ambitious goals in science. It is heartening to see that in today's world a woman can reach this height and command such respect from the scientific community the whole country and indeed the world. However, the progress of women in science and science leadership roles has been a slow and difficult journey all over the world (Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, 2012) but intelligent, brave and strong women have persevered against many odds over centuries to bring about this dawn of a new era. We are now able to view on television and read about highly

[1] https://newsroom.unsw.edu.au/news/science-tech/unsw-scientist-michelle-simmons-australian-year

successful women in science, such as Michelle Simmons, and marvel at their achievements which are far beyond the dreams of their predecessors. No doubt Professor Simmons and her team will continue to persevere with the quantum computer race and achieve future success.

This longitudinal study has a linking theme as it deals with the perseverance of the human spirit through female students' involvement in science education. It documents the interests and attitudes of eight female students and follows their academic journeys through university, attempting to identify the factors responsible for compelling them to complete their science degree. It aims to consider the influence of science teachers, the school and home environment, the role of society, scientists, leaders and career opportunities on the students' decision to choose a science degree and career.

1.2 The Focus of this Study

The researcher has had the opportunity and privilege of being a secondary science teacher for many years and a department head in recent times. During this time, she has taught and mentored many students, mostly females. Along with other teachers, she has closely followed the successes and trials of her students and has enjoyed hearing details of university encounters when she has met these students after some years. It has been a motivating factor to continue to be a mentor for some students and fellow colleagues and she has spent many happy afternoons, discussing over a cup of coffee, the fact that so many girls from her school have completed science degrees and have gone on to have careers in science. Women in science have thus become a reason for this formal study.

While there are many students who change their career path and end up with degrees different from the one they first started with, there have been a few who have not only continued to study science but have come back to speak to Years 11 and 12 students and their teachers about their university experiences. The focus of this study is therefore to present case studies to identify the influential factors which have led to these students' success rates. Though these findings may not be typical of what is happening in other schools in the state and the country, they are nevertheless of significance to the educational field and may influence the way school administration and university selection is organised in the future.

1.3 Research Objectives

Objective 1: To determine the interests and attitudes of secondary female students towards science education?

The research questions related to the first objective are:

1a: Who are the potential science students who may take science in university and have science careers?

1b: What are the student's attitudes and interests in science and science careers?
1c: What are the sources of the students' interest in science in school?

These research questions were formulated to obtain as much information as possible from the participants through discussion with students and data from student questionnaires. Early questionnaires were related to student attitudes and interests in science and science careers. School science staff members and administrators were also engaged in discussion and responding to questionnaires to help understand what teaching strategies and classroom climates might be responsible for sustaining students' perseverance of interest in science and pursuing science careers.

Objective 2: To investigate in depth the correlation between school examination results and the choice of subjects for a university degree and to investigate the personal traits which influence the academic performance of the student

The research questions related to the second objective are:

2a: Does the student's performance in the School Certificate and Higher School Certificate examinations, correlate with her subject choice for a degree?
2b: Which undergraduate and post graduate degrees did the participants complete successfully?

2c: What role did the student's personal characteristics play in helping her to conclude the degree she had started, and in some cases, go on to study for post graduate degrees?

Scanned documents were obtained from students' School Certificate and Higher School Certificate results (Chapter 5). From these certificates the researcher sought to identify connections between students' performance in science subjects and their choice of subjects for their university degree. Once the students had left high school and embarked on their academic journey for three years the researcher maintained

contact and recorded their yearly progress, documenting their grades in the units of university study concerned. The researcher made notes of difficulties these students did experience especially in the first year at university which was a giant leap from high school to independent university study. In addition to this the researcher examined in depth the consistency of the student performance in the first three years of the science degree and attempted to find the link between the students' academic performance in the university degree and their own personal characteristic traits.

Objective 3. To analyse the internal and external factors which have influenced the students' decision to persevere with science education.

The research questions related to the third objective are:

3a: What are the external factors identified by the participants themselves, which may have contributed towards their success in completing their academic journeys?

3b: What are the external and internal factors identified by the teachers of the participants, which may have contributed towards their perseverance in science education?

3c: What factors can the mothers of the participants identify, both within the family and externally, which can be attributed to their daughters' success in school and university?

To answer these research questions, the research has sought to investigate the influence of the home, role models, mentors and close friends on the students' decision to persevere with their study. In addition, the social environment and career opportunities that contributed to the students' decision to persevere with the study of science were considered. These are leading research issues which became part of the discussion with the participants, their parents and mentors. A summary of the research methods follows with more details are in Chapter 3. Figure 1.1 gives an overview of the three objectives of this longitudinal study and the methods used by the researcher for achieving these objectives.

The First Objective: Interests and Attitudes • The three research questions related to the interests and attitudes of the participants are discussed in detail. • Early attitude questionnaires TOSRA, PAU 1 and interviews are used to collect initial data. • Case studies of the participants based on this information are developed and documented.
The Second Objective: Academic Journeys • Students' results in two external school examination are compared and linked with their choice of subjects for an undergraduate degree. • University results are also examined and linked to career choices or further postgraduate study. • Students' own characteristic strengths and personal traits are discussed using the Questionnaire PAU 2 data and from consequent interviews with the researcher. • Case studies of the participants based on this information are further developed.
The Third Objective: External and Internal Influences. • Data are obtained from participants through Questionnaires PAU 2 and PAU 3. • Data are obtained from four teachers through Questionnaire T 3. • Data are obtained from the mothers of the eight participants through Questionnaire M 4. • A literature review is created based on the data obtained from the questionnaires.

Figure 1.1 *Overview of the Thesis Objectives and Process for Achievement.*

1.4 Research Methods

Research Design

The basis of this theory is the Grounded theory. In this method there are systematic guidelines for data collection and analysis (Charmaz, 2000, 2011; Morse, 2016). Because of this method of data collection, a framework can be constructed which would explain the collected data. Therefore, formal data such as interviews which are structured and informal data such as observations which are unstructured can be used to develop theory. The process of grounded theory building involves five analytical phases such as research design, data collection, data ordering, analysis of data, and a literature comparison (Corbin, 1990; Silverman, 2015; Strauss, 1998). The main goal of the documented case studies has been to identify reasons for the students to make positive decisions to persevere with the study of science. In this research, both qualitative and quantitative methods were used and are discussed below.

Participant Observation

The researcher observed the classroom settings and laboratory work as the students performed their laboratory and class work. Based on early science attitudes as obtained from the initial questionnaires 16 participants in Years 11 and 12 were chosen for the study. After they had completed school and were enrolled in various undergraduate science degrees in university, the cohort was reduced from 16 to eight. The reduction was largely because some participants changed their degrees and others decided not to be part of the study. Only one participant joined the cohort after school and was from a different school.

The research sought to identify the similarities and differences between the various case studies in this longitudinal study. These details have been carefully documented as reviews of each participant's progress in science from the various vantage points described below. The research has involved content analysis and in-depth understanding of the current information collected over a period of six years.

Interviews and Structured Questionnaires

The data were collected in the form of discussion in semi-structured interviews and structured questionnaires. Students responded to a questionnaire - the Test of Science Related Attitudes (TOSRA) (Fraser, 1981) - to measure their science attitudes. Questionnaires were also given to parents, teachers and administrators. A questionnaire was designed for the mothers of the study participants after they had completed their degrees because earlier data was pointing to the fact that the home and parents played a significant role in the students' success in completing their degree.

Similarly, some questionnaires were designed while the participants were halfway through their degree. Samples of these questionnaires are included in Appendices.

Collection of Course and Examinations Results

The researcher collected information in the form of examination results both from each student's school records as well as from the three-year degree or five-year degree. Examination results were scanned and emailed to the researcher in situations when direct contact was not possible due to time constraints. The school provided details of each student's performance with the permission of the principal, who had a copy of the ethics form.

Evaluation

The five analytical phases of the grounded theory have been evaluated against four research quality criteria namely construct validity, internal validity, external validity and reliability (Corbin, Strauss, & Strauss, 2014). Construct validity has been a method of analysis by establishing clearly specified operational procedures, in the form of planning and conducting the research using multiple data sources and the preparation of the case study database (Glaser & Strauss, 2017). Internal validity involved establishing relationships between the researcher and person being interviewed and was enhanced by triangulation interviews with observations, to avoid and/or reduce bias. The vast amounts of data were coded, and the analysis process was both manual and computerised. This coding procedure further enhanced internal validity. External validity required establishing a domain towards which the research findings were directed. At the literature comparison phase of this study the emergent theory which developed from this research, has been compared with conflicting and similar frameworks, thus enhancing the internal and external validity. (Glaser, 1992). The researcher compared the case studies of the students looking for similarities, differences and sought to identify influential factors that reinforced and motivated students to study science. The multiple data sources and structured interviews over a period of three to six years and the precise coding, descriptive statistics, content analysis and in-depth understanding of current instruments have all contributed towards enhancing reliability. Details of these methods are provided in Chapter 3.

1.5 Significance of this Study - Interest, Attitude, Motivation, Success.

Although there are fewer prejudices and obstacles towards the education of science for female students today, there are still less females taking up science and mathematics in comparison to males (Allegrini, 20I5). Interest in science begins before secondary school and research has shown that the science, technology, engineering and mathematics (STEM) pathway is composed of a series of choices and achievements that commence in childhood and adolescence (Wang & Degol, 2013). Interest in science in early secondary school in Year 7 may determine the choice of science as a subject in Year 10, which in turn may result in a science career. Research on gender interests and abilities has shown that women and men are equally capable and interested in science and mathematics at an early age (Archer et al., 2012). Hence, encouragement from teachers during the early secondary years will play a role in developing confidence in female students to study science and mathematics.

In recent years, the New South Wales Education Standards Authority (NESA) has included STEM (science, technology, mathematics, and engineering) into the state's middle school syllabus. The Australian Industry Group released a final project report in June 2017 on strengthening school-industry STEM skills partnerships, where it reports on the implementation of STEM in various states in Australia following the example of New South Wales.

> In 2015 it seemed that the New South Wales Department of Education was almost unique in its implementation of the Integrated STEM Program to state schools across New South Wales. However, during 2016 it has become very apparent that there is a growing focus on STEM and a noticeably increased awareness by education systems, schools, teachers and parents about the importance of STEM education and skills. There is a growing interest in embedding a stronger focus on STEM education into school systems (pp. 15).

In industry, 75% of jobs require STEM skills, so it is important that these skills are developed in schools and that students of both genders are encouraged study STEM subjects. New jobs are being created which require skills which would be better developed as soon as possible to adequately prepare children for their future occupation, Teachers likewise would need be suitably educated to implement these necessary skills and resources (Corlu, Capraro, & Capraro, 2014). However, this

introduction of STEM is an important step for building interest in practical and applied science for both male and female students and may have impacts on their future science career choices.

Even though this new movement in education has been implemented recently, and therefore by itself has not influenced the attitude of the eight participants, it should be noted that for seven of the eight participants, the school had organised chess, science mathematics and robotics clubs as extra- curricular activities and so had been incorporating the principles of STEM in an informal way. These activities and small projects related to these activities, no doubt played a role in encouraging the participants to have a positive attitude to science and details of the participants attitudes are documented in later chapters of this thesis.

1.6 Structure of Thesis

This thesis has been organised into seven chapters of varying lengths. The first chapter introduces the research topic and outlines the focus, background and significance of the study. It explains the research design and objectives and gives the outline of the thesis framework. The second chapter is a review of the literature that brings together recent and relevant literature connected with this study. It shows an in-depth understanding of the topic and reinforces the challenges and problems that the researcher is addressing through this longitudinal study. Moreover, this review seeks to introduce clarity of the topic and unprejudiced opinions and findings of other researchers and writers. The third chapter clarifies the methodology of the thesis by explaining the methods of data collection using the structured questionnaires interviews and examination transcripts. It also gives the reader a brief introduction to the eight participants who make up this study.

Chapter four goes into detail to discuss the first objective by using the three research questions related to obtaining information from the participants about their interests and attitudes towards science. It gives an overview of the eight participants' early attitudes towards science and their initial goals for future science degrees and careers. In a similar manner, Chapter five discusses the second objective by comparing the school and university courses, using examination results and personal questionnaires, to document the eight participants' academic journeys in detail. Chapter six makes a general review of the third research questions indicating the influence of internal and

external factors on the academic progress of the students. These influences are identified by teachers and family members as well as by the participants themselves. In the following chapter seven the researcher uses analysis of the final data to write concluding literature reviews of the eight case studies. The study concludes with a discussion of its limitations and with recommendations for the field of education.

1.7 Summary

There have been fewer longitudinal studies carried out in Australia and overseas due to time constraints for younger researchers who may not have yet joined the work force and due to financial limitations. This study therefore has significant value as it was conducted over a period of six years. The initial place of the study was within the researcher's daily work. The researcher has been able to observe collect data and document these case studies for a longer period without the usual restrictions to produce results quickly. During this time teachers and administrators and well as parents and mentors were also connected with the study. There have been many changes in the lives of the students involved while they were under observation mainly emotional and intellectual growth. The overall findings which have arisen from the data alone have been positive.

CHAPTER 2

A LITERATURE REVIEW OF WOMEN IN SCIENCE AND IN SOCIETY

"If a woman possesses a special gift for the tasks of theoretical physics and also the drive to develop her talent, which does not happen often, but does happen on occasion, then I consider it unjust, from a personal as well as an objective point of view, to categorically deny her the means to study" ... Max Planck (Sime, 1996, p. 25).

2.0 Overview

Women have played a role in contributing to science education and science research both in the past and present. Though their contributions have not always been known or acknowledged by the rest of the world until recent times there is now a greater awareness of the significance of their contribution. This chapter examined the history of women in science and speculated at new directions for women in science education and science careers. This chapter also has discussed the influence of parents, siblings, teachers, scientists and the media on science attitudes developed by students. The cultural background and socio-economic factors which play a role in the education of female students are considered. Ultimately the opportunities which a woman may have today in science-related fields are discussed against the role of motherhood and the consequent interruptions to a career in science.

2.1 History of Women in Science

The scope and focus of this study do not allow for detail on every woman's contribution to science but seeks to give an outline using interesting and relevant examples to reinforce the importance of the history of women in science.

When one thinks of women in science the name Marie Curie probably comes to most people's minds as she is remembered for identifying two elements and for receiving the Nobel Prize twice both in physics and chemistry (Chiu & Wang, 2011). However, there have been many women before her, who have made contributions to science, but who may not be as popular or as well remembered. The history of women in science goes back as far as the fourth century AD. One of the earliest women known to have

contributed quite significantly to science was Hypatia who was the daughter of Theon (Reddy, 2015). She and her father lived in Alexandria in Egypt. While he was a mathematician and astronomer she learned from him to become a great teacher, astronomer, mathematician and philosopher. It is a belief that she was responsible for editing books such as Ptolemy's *Almagest* and *Handy Tables*. Sadly, she was murdered by a mob who felt threatened by her teachings.

Maria Dzielska (1995) in her book *Hypatia of Alexandria,* reports that 'she moved in high government circles surrounded by dignitaries and wealthy students' and believes that Hypatia would have "almost certainly had some influence on political and social life in Alexandria" (p. 41). The lectures took place in Hypatia's house and she taught both astronomy and mathematics. In addition to this she also gave public lectures "She possessed great moral authority; all our sources agree that she was a model of ethical courage, righteousness, veracity, civic devotion, and intellectual prowess" (p. 103). Margaret Wertheim (1997) mentions in her book *Pythagoras' Trousers* that "The great era of Greek mathematical science, which began with the birth of a man, finished with the death of a women (Hypatia)" (p. 37). Thus, we can see that Hypatia was the mother of women in science.

It was a long time before another woman of this calibre would be able to lead in science. In fact, the next woman who could even be compared to her for scientific contributions to society came much after the Renaissance (Laven, 2003). One might wonder what women were doing during the period of the Renaissance which took place between the 14th and 17th centuries. According to Mary Lavan (2003) in her book *Virgins of Venice*, the Renaissance was a time of mental revolution the awakening of new thinking, the age of great discoveries and progress in the fields of study. Science subjects such as physics and biology developed tremendously and so did mathematics, physiology, chemistry, art, and astronomy. This was a period of the explosion and demonstration of knowledge. Science and scientific discoveries and theories made such great progress that the foundations of our modern science were laid during this period. The scientists responsible for this great movement were all male as documented by history. For example, to name a few, the Polish astronomer Copernicus (1473-1543) gave the world the heliocentric model of our solar system (Hall, 1994). His theory suggested the revolution of the earth around the sun instead of the geocentric model which taught that the sun was moving around our earth.

Galileo (1564-1642), the Italian physicist astronomer and mathematician, used this model and his telescope to prove this was true (Mason, 2002). Galileo improved the earlier telescopes, made advances in the physics of accelerated bodies and contributed practical proofs to the field of astronomy thus overturning previously held beliefs. Kepler (1571-1630) gave the world the three laws of planetary motion, all of which are the foundation of physics courses which is used in schools today.

The physics course in New South Wales (2002-2018) had a topic called Space for the Higher School Certificate course and students studied Kepler's third law which relates to the period of a heavenly body being mathematically connected with the radius of orbit. In fact, we would not be able to send up our communication satellites to correct and intended orbits with the right calculation and so successively had it not been for this great male scientist (Pickover, 2008). One cannot leave out another outstanding male scientist, Sir Isaac Newton (1642-1727), who is known widely today for his theory of universal gravitation and for the related laws of gravitational attraction of heavenly bodies. However, Newton also made very valuable contributions to mathematics laying the foundations of both differential and integral calculus (Westfall, 1983). It is possible to name more male scientists such as Leibnitz, Fermat and Descartes and Leonardo Da Vinci; however, what was happening to women during the period of the Renaissance when their male counterparts seemed to be at the peak of their intellectual progress? Why were women so absent?

In their article, *A Short History of Women in Science*: *From Stone Walls to Invisible Walls*, Barnett and Sabattini (2009) discuss Cambridge historian Mary Lavan's book *Virgins of Venice* (2003) referring to the life of women in the Renaissance.

> Ironically, as they watched the lives and rights of their husbands, sons and brothers expand during this period, women's lives contracted. During the height of the Renaissance, when science was flourishing, women had only four life options: enter into a marriage, usually arranged; enter into a convent; work as a maid; or become a prostitute. (p. 4).

The article discusses further that the price of the dowry was so high that parents urged their daughters to enter the convent, where the fee for joining was much lower than the dowry required to get married. Many girls were afraid of childbirth and as a result the convents were filled with young women. While in the convents they learned

traditional subjects such as sowing and embroidery and certainly not science and mathematics. It seems that this was period of sexism where the careers and study areas for male and female were becoming distinctly separate (Kuehn, 1996).

However, by looking at the progress of science from the 17th century to the present times, there were women scientists who did break all barriers and emerge as leading scientists. This was a period of scientific revolution. This changing face of science did not stop women from taking an interest in telescopes and microscopes, which became 'toys' for the aristocracy. During this time Margaret Cavendish (1661-1717) who was the Duchess of Newcastle and Anne Conway (1631-1679), who was an aristocrat, wrote treatises of natural philosophy revealing their knowledge of the scientific theories of that time. Women thus began translating scientific documents.

The most famous of these women Emile Du Chatelet, translated Newton's *Principia* into French and expanded his work putting theories to practice and developing further theories herself (Terrall, 1995). Emilie du Châtelet, is regarded as one of the principal illuminators of the Enlightenment (Bodanis, 2009). She "played a great role in energizing the French school of theoretical physics" (p. 283). She has been credited with the development of significant concepts in physics.

Merian's book *Metamorphosis* (1705), which contained detailed illustrations of the life cycles of various insect and plant species, is the foundation of the study of Ecology. Hence women were contributing to science in an indirect way during this time. Clemence Royer (1830-1902) translated Darwin's *Origin of the Species* into French in 1862 (Pickering, 1999) and Marie Bonaparte (1882-1962) translated Freud's works (Bertin, 1987).

In the United States, Elizabeth Blackwell (1821-1910), who became the first woman Doctor of Medicine, was a teacher and founded the first medical school for women doctors in America (Stone & Priceman, 2013). Rosalind Franklin (1920-1958) was a pioneer molecular biologist whose research at Cambridge University on X ray crystallography led to present understanding of the double helix DNA molecule. However, though her contributions to science were extraordinary her male colleagues Watson Crick and Wilkins were awarded the Nobel Prize (Albright, 2014).

Similarly, Lise Meitner (1878-1968) who worked with Otto Hahn and Fritz Strassmann in the Kaiser Wilhelm Institute for Chemistry did not receive the

recognition she deserved for her work on radioactive fission (Sime, 1990). The Second World War had interrupted her career and as she was Jewish by birth, she had to flee to Stockholm in Sweden to escape the Nazi occupation (Rife & Grove 2001).

From the period after the Second World War up to the present time women have participated in all spheres of science such as engineering, chemistry, physics and astronomy. Many women have qualified as medical doctors and have obtained doctorates in science and mathematics. They have taught in schools and universities and have entered hospitals to work not just in traditional roles such as nurses or receptionists but as ultrasound and MRI technicians as well as medical physicians. (Clark, Zuccala, & Horton, 2017). Pharmaceutical companies seem to employ women today in the laboratory as well as at the front desk (Dhatt, Kickbusch, & Thompson, 2017). Women are working in research and forensic laboratories and have even become astronauts at NASA taking part in space exploration and research programs. How did this come about? The next section will look at the opportunities which were and are still available for women in different branches of science.

2.2 Opportunities for Women in Science

As women of today have entered different spheres of science and technology, it is necessary to see historically how this apparent equal opportunity has occurred. Are there equal opportunities for male and female scientists? What obstacles had to be overcome for women to succeed and be accepted by society? This review does not go back too far in history simply because the more recent past is more relevant to the study which is attempting to identify factors responsible for female students persevering in the study of science in the 21st century. The women mentioned in the history of science were exceptional and therefore succeeded against the odds that they encountered. Despite this these women faced some discrimination. One must now look at the ordinary women and research what were the opportunities available to them in the field of science.

If women's contributions to science in the eighteenth century were related to translating books written by their male counterparts, we can see that due to the social restrictions of that period the opportunities were not equal for both genders. Women were restricted largely by the biological factor of childbearing and child rearing.

Wealthy women could afford to have a better education as well as having more time, but the average woman could not, in any way, compare with an average man for an opportunity to have a successful science education and career.

Nevertheless, documentation of women's achievements and contributions to science have been made from the eighteenth century, originally like encyclopaedias listing details with dates. In the chapter prepared for the American Enterprise Institute by Barnett and Sabattini (2009) *From Stone Walls to Invisible Walls*, the authors give a brief history of women in science in America:

> Until the early 19th century, girls' education was restricted to informal learning at "Dame Schools" where instruction was offered by female teachers, usually in their homes. Young girls were taught basic reading and writing, embroidery, and other "feminine" skills. From the mid-1820s there was such a rapid spread of education for women in the U.S. that the U.S. led the rest of the world in public and private education for girls and women. However, girls were locked out of science education by the stone walls of the male-only colleges (p. 5).

Similarly, Margaret Rossiter, in her book *Women Scientists in America: Struggles and Strategies to 1940*, has documented in encyclopaedic form the opportunities for employment in science. It seems that colleges opened in the mid-1800s and extensive courses were offered. However, even though women entered colleges they were not allowed into male colleges as there was sexist segregation at that time, (Rossiter, 1982).

Sandra Harding, in her book *Whose Science? Whose Knowledge?: Thinking from Women's Lives, (2016)* states that 'The consciousness of the women who did find a place in science was often not feminist"(p. 23). She adds

> In order to succeed as scientists, these women usually had to force their lives as closely as possible into life cycles designed to accommodate the lives of men in patriarchal societies. Their possibilities of marriage and children were severely diminished in ways that never affected their brothers. (p. 23).

Once these deserving brave and pioneering women obtained their degrees there was still a problem with employment (Milkman, Akinola, & Chugh, 2015). If women were employed, they did not get equal pay, had to leave the job if they got married or pregnant, and because of this often did not work with the same consistency as men in

the same role. It is no wonder then that the ordinary woman who strived to have a science education and a career in science did not reach the level of a masters or a doctorate (Maher, Ford, & Thompson, 2004). Some graduate schools continued to be exclusively for men and it was only in the 1960s that Harvard and Princeton allowed women to complete their doctorates (Ulrich, 2004) Harvard's Graduate School opened to women in 1963 (Silverberg, 2006). Women faced difficulties in employment and if a woman scientist married a male scientist she could not work in the same institution. Because of this, she would be unemployed if the town was small and did not have another academic institution or she would have to travel to another institution. As Margaret Rossiter (1982) adds in her book referring to a woman scientist: "Once she married a scientist of greater reputation, a woman's own independent work would all too easily be dismissed as merely a small part of his" (p. 331).

In addition to this problem women faced unfair competition with men when they applied for job (Oakley, 2016), and this was identified in a study by Steinpreis, Ritske, and Anders (1999) using 238 academic psychologists, both male and female, listed in the 1997 Directory of American Psychological Association. The psychologists were sent one of four different versions of a curriculum vitae, a questionnaire and a self-addressed stamped envelope. The information came from a female scientist, but for the exercise the names were changed to traditional ones both male and female. The questionnaires asked participants whether "they would hire the applicant, tenure the applicant, and what starting salary they would offer the applicant. Participants were also asked to rank order what factors influenced them most when reviewing the vitae" (p. 514).

The conclusions of this study were that "Both men and women are significantly more likely to vote to hire a male applicant versus a female applicant with the same academic record" (p. 509).

It is therefore disappointing that at the turn of the century women were still facing a bias to employment in the field of science (Clancy, Lee, Rodgers, & Richey, 2017), and that there are few women in science in the United States, (Hill, Corbett, & St Rose, 2010). This is true for other countries as well. For example, in Spain, even though there are more women professors in universities than in other European countries, appointments were generally made based on internal networks and these have been

found to constrain the career opportunities of women (Vasquez-Cupeiro & Elston, 2006).

In the field of research, gender imbalances persist. The research paper titled *Global Gender Disparities in Science* (Larivière, Ni, Gingras, Cronin, & Sugimoto, 2013) points out that-

> Globally, women account for fewer than 30% of fractionalized authorships, whereas men represent slightly more than 70%. Women are similarly underrepresented when it comes to first authorships. For every article with a female first author, there are nearly two (1.93) articles first-authored by men (p. 212).

2.3 The Socio-economic Factors which may affect Female Science Education

Research conducted in Australia by Rothman (2003) showed parental education levels, their occupations and income are major factors contributing towards the educational achievement of their children. These socio-economic factors are more influential than 'race, ethnicity or immigrant status'.

The socio-economic status (SES) of the family thus plays a major role in determining education achievement. Research suggests that students with higher academic success are more likely to hail from higher SES backgrounds (Berger & Archer, 2016; Sirin, 2005).

Hunter and Schwab, (1998) suggest that many indigenous people do not invest in education, since they do not see the relationship between the education of their children and the employment opportunities they may have because of this education.

Poverty and parental ignorance may also play a part especially in the developing world where a female child may have to stay at home and help with housework thus sacrificing her opportunity for a normal education. Yet even in the developing world, women, if educated at primary level, can make contributions to the economics of that country by working in areas such as farming and industry (Floro & Wolfe, 1990). In progressive countries such as Japan, Ono, (2004) suggests that the gender disparity in

higher education and later in employment stems from the unequal resources put aside by parents for their sons and daughters.

Campbell and Wu (1996) analysed talented students across five countries based on mathematical olympiads and concluded that the students' learning was affected by the home environment and family network. According to them, the family's level of encouragement, expectations, and education activities in the home are related to socio-economic status. Research by Song and Hattie (2004) reinforced this concept that the families and the learning environments they created due to their socio- economic status affected their child's academic success.

2.4 Influence of the Parents on Choices made by Students in Science Education and Careers

Parent attitudes towards science and science education are known to play an important role in shaping science aspirations in young persons (White & Harrison, 2012). Similarly, parental advice and influence seems more important than that from teachers and friends when applying for a job or when deciding on a career (Cridge & Cridge, 2015). Parental education almost directly correlates to university ambitions (Roska &Potter, 2011). Simpson and Oliver (1990) observed that parental attitudes towards science, especially that of the father, had a positive influence and were related to the child's achievement in science.

Longitudinal studies conducted by Bleeker and Jacobs (2004), have confirmed the finding that children's concepts of their own abilities can be related to the expectations of their parents. This research showed that mother's perceptions of their adolescents' abilities were related to career choices made later. Yee and Eccles (1998) in their study on the parents' perceptions of the mathematical abilities of their children, found that parents had different reasons for their sons and daughters' success. Parents felt that their sons had talent which contributed to their success whereas the daughters' success was credited with hard work. Crowley, Callanan, Tenenbaum, and Allen (2001) observed parents and children using interactive science exhibits at a museum. They found that "parents were three times more likely to explain science to boys than to girls" (p. 258).

Research by Mullis, Mullis, Cornille, Ritchson, and Sullender (2004) in Florida noted that parents can take many positive steps to help their children by encouraging them to read good books, complete homework and spend less time watching television. More recent observations by Cole (2011) suggests the importance of the child-parent partnership in education from early beginnings.

Children may not be influenced by external factors if there is considerable parental involvement and interest in home learning activities. These other factors could be the distractions caused by social media and the misuse of technology

Children today must use the computer to complete school assignments and even mathematical calculations are often done online in the form of simple exercises and tests. Parents are required to know enough about the nature of the school task to supervise their children and monitor them from time to time, so that they are not distracted by computer games. Internet connections should be well filtered so that school students are not distracted by irrelevant and dangerous material. Parents can encourage their children to read by visiting local libraries and by using reputed online libraries. Family discussions about current events in the literary and scientific world could also prove beneficial to children.

In the article *Parents Who Influence Their Children to Become Scientists: Gender and Parental Education*, Sonnert (2009) in an examination of a sample of American scientists found that women scientists were more likely to mention their parents as career influencers. A study by researchers in the UK on student attitudes towards science and science-based careers, found that there are many highly influential external factors responsible for shaping these attitudes such as work experience, teaching quality and teacher enthusiasm but also included parental and family attitudes to science as important (White & Harrison, 2012).

2.5 The Influence of Siblings

This research also investigates the family background of the participants, compares the size of the family, and attempts to assess whether the siblings in the family played a significant role in encouraging and influencing the participants on their academic journey in science education. Some of the participants were from large families while others were not. All the participants had siblings.

According to Brody (2004), a person's well- being and social adjustment in life can be related to the quality of his or her early sibling relationships. Furthermore, research has shown that in large families siblings can act as role models and influence one another's development (McHale, Updegraff, & Whiteman, 2012).

Research by Hauser and Wong (1989) noted that the older siblings influenced the education of younger siblings through role modelling or by social facilitation. Similarly, research has shown that first born siblings are more likely to be in leadership roles whereas later born siblings are more likely to be followers (Whiteman & Christiansen, 2008). Older siblings' academic engagement can influence the academic engagement of younger siblings (Bouchey, Shoulberg, Jodl, & Eccles, 2010). Although siblings are building blocks of family structure and key players in family dynamics, their role has been relatively neglected by family scholars and by those who study close relationships. McHale et, al. (2012), and Dunn (1983), concluded that sibling relationships are unique in that they encompass both the complementary interactions typical of adult–child relationships and the mutually influential interactions of peers.

2.6 The Influence of Primary Teacher Attitudes towards Science Education

In Australia, there has been a long discussion and much concern that many primary school teachers do not teach science with enthusiasm (Yates & Goodrum,1990). The reasons are many, but the main point is that many primary teachers lack confidence and competence for teaching science (Appleton, 1995) and have low self-efficacy about being able to teach science effectively (Appleton, 1995). Similarly, research in Scotland has shown that primary teachers may encounter some difficulties when teaching science and technology due to a lack of specific subject knowledge or a lack of confidence (Harlen & Holroyd, 1997). This research showed that there were some ideas that primary teachers could easily understand but others required extensive in-service education. The research suggested that subject knowledge was not the only factor that helped primary teachers to develop confidence which is so essential towards the teaching of science. Research by Palmer (2002) has shown that students with a negative attitude because of poor science teaching in primary school can in turn continue the cycle if they become primary teachers. However negative attitudes towards science can change. Palmer's research found that the improvement of attitudes

towards science was possible and could be the result of the influence of a tutor, teaching strategies and external validation.

Teacher attitudes towards science and science education has been found to influence student attitudes. Primary school teachers are not expected to specialize in subjects to complete their preservice education rather, in most countries including Australia, they are expected to provide teaching in all areas such as history geography science, mathematics, music, drama, art and sport. To improve teacher confidence and student learning of science in primary school a program called *Primary Connections* was introduced in all schools in New South Wales in 2005. This program is a teacher professional learning program supported with curriculum resources that aims to enhance learning outcomes in science and the literacies of science. Introduced following the 2001 national review of the status and quality of science teaching and learning (Rennie, Goodrum, & Hackling, 2001), research data from the trial of *Primary Connections* indicated that the program had a positive impact on teachers, students and schools (Hackling, Peers, & Prain, 2007).

2.7 The Secondary Teacher's Influence on Science Attitudes and Careers

Secondary science teachers can influence students' love or dislike science. Their influence may occur from the students' entry into secondary school and possibly continue until the student leaves school in Year 12. A science teacher who loves his or her subject and teaches with enthusiasm is likely to motivate students to love the subject and choose science as a subject for senior years and university.

Lederman (1999) asked the question about whether the teacher's understanding of the nature of science influenced scientific practice. Previous research (Abd-El-Khalick; Bell & Lederman, 1998) had shown that teachers' conceptions about science did not influence their practice. However, Lederman's (1999) research into the factors which affected classroom practice led to the conclusion that student success was based on the ability of the teacher to transform understanding of science into actual practice.

The teachers' instructional intentions had a significant effect on their classroom practice. Lederman's argument is that teachers may be able to develop the skills necessary for transforming their knowledge into classroom practice once they have internalised the importance of the nature of science.

Universities Australia published a report in 2012 based on research which examined first year university students' attitudes towards science, technology, engineering and mathematics (STEM) (Lyons et al., 2012). The research compared the responses of 701 STEM and 851 non-STEM students in their attitudes towards science and traced influences on degree completion back to high school where secondary students interest in science and mathematics to determine if success was aroused by good science teaching practices. The first-year university students rated good teachers as the most important individuals in their decisions to take STEM courses. They considered the teachers to be more influential than parents and peers and that personal encouragement from teachers influenced female students considerably enough to help them to decide to take up STEM courses. This finding was consistent with earlier research showing that students also considered science teachers to have been the greatest influence in helping them decide whether to take science courses in Year 11 (Lyons & Quinn, 2010). This stated influence therefore highlights the importance of good science teaching in secondary schools and teachers should realise their potential and ability to form the scientific career paths of their students. Research on gender bias (Williams, Phillips, & Hall, 2016), (Shapiro & Williams, 2012), and (Wang & Degol, 2016) has suggested changes for encouraging females in STEM subjects.

In another report which compared STEM internationally with respect to Australia, a group of researchers showed that comparison of educational practices and policies can help provide an informative window through which we can better make judgments about key features of Australian STEM practices (Marginson, Tytler, Freeman, & Roberts, 2013). Among suggestions made regarding secondary science teachers in Australia, was that students with higher degrees such as doctorates should be encouraged to take up teaching and be offered higher salaries as incentives. Other suggestions were that gender-based scholarships be issued especially in the field of engineering, secondary science teachers be engaged in specific professionally developed programs using an evidenced-based approach, and enrichment programs be offered for secondary science and mathematics teachers to help them be the best teachers they could be.

2.8 Media Influence on Science and Science Education

There is no doubt that leading scientists in Australia and overseas have now, with the help of the media, reached out to the public far more readily than in the past. (Dingwall & Aldridge, 2006). The digital revolution has made access to writings, journals, and scientific papers much more accessible. Therefore, students now have access to information about recent discoveries, trials of drugs and their results, research into cancer treatment, nanotechnology and communications technology. In addition to this, the media has taken to glamorising space-related episodes, astronauts are now on U-tube videos doing more than just scientific experiments, even producing musical hits in space. A fine example of this is Chris Hadfield, a Canadian astronaut, who has entertained from space using social media to motivate and promote science (Hadfield, 2013).

Similarly, scientists have used their knowledge and charisma to communicate with the public. Notably one such scientist is David Attenborough who won a scholarship to Clare College at Cambridge University in 1945. He studied geology and zoology. He graduated in Natural Sciences and went on to write books and work on television programs. There would be very few science teachers who did not use his videos to enhance their science lessons. Attenborough has brought science into the lives of students with his brilliantly photographed documentaries and his gentle narration, (Attenborough, 2002; Burgess & Unwin, 1984). With his more recent documentaries are *Planet Earth II* (2016) and *Blue Planet II* (2017), he has been a media leading scientist of the natural world who has influenced students to know more about botany, geology and zoology than they would from reading textbooks.

Other scientists have brought physics and astronomy to the forefront using the media of our age. One such scientist is Professor Brian Cox, who is a physicist and professor at the University of Manchester UK and a working scientist at the Large Hadron Collider at CERN, is a popular TV presenter, gives TED talks and has written many scientific books. He is also known for *The Science of Doctor Who* (2013) received the Michael Faraday Prize in 2012 and had been in his early years of university a rock star. His book *Wonders of the Universe* (2011) co-authored with Andrew Cohen has been made into a BBC Television show. All these factors contribute to his influence on young science students.

2.9 The Cultural Influence on Science Education

Cultural backgrounds of students may appear to have a direct influence on their choice of a science career. Parents of Asian students have a reputation for pushing their children to achieve well in primary and secondary school and to encourage them to study science and mathematics as well as take up careers in these subjects, (Watkins, Ho, & Butler, 2017). In countries such as Singapore, China, India, Korea and Japan there are high achievement standards for science and mathematics education (Kaur, 2010). Indeed, students of Asian parents in America and other countries of the western world including Australia seem to be achieving very well in science and mathematics. In a study on parents, diversity and home culture, researchers attempted to discover how parents in schools in New South Wales from diverse cultural backgrounds approach the school system and perceive their role in their children's education (Cardona, Watkins, & Noble, 2009). Research on the parental background of children found that Indian and Chinese were able to provide their children with routines and activities which further enhanced and reinforced their education as opposed to parents of Pacific Island or Afghan origin. One reason was that these parents were themselves well educated and set aside resources for their children's education. Consistent with this finding, Donnelly (2015), director of the Education Standards Institute and a Senior Research Fellow at the Australian Catholic University, referred to secondary school results in Melbourne Victoria stating that Australian-born students had been placed third academically behind foreign-born and first-generation students from migrant families. He stated that that private schools in Melbourne and Sydney did well in external examinations due to the large populations of Asian and Indian students.

In addition, male and female students from different cultural backgrounds especially those of Asian and Indian origin are more likely to attend tutorial classes run by education academies on weekends which have given rise to a new academic industry. Parents who were born in India tend to send their children to extra coaching classes especially in science and mathematics. (Aris, 2017). Parents of government school children who pay lower fees save money for tuition classes some starting in Year 10. Parents of private school also make the effort to send their children for Saturday tuition hoping that the additional study, rigorous homework exercises and special study notes will make an overall difference to improving their education.

2.10 Interruptions to a Science Education or Career

As women who study science in school and decide to take up a science degree, the world may probably appear to be a fair place and opportunities may seem to be the same for females as they are for male students. However, there are some disappointments ahead for those female students who may be in a relationship and who may (though not by choice) become pregnant. They will, in a situation like this, have to take time out from study, first to have the child and then to look after the child for at least one year (Monosson, 2008). Extended families are becoming less common and there are smaller chances of getting help and support for childcare and child-rearing from family members. Furthermore, the independence of the young student may not allow for family interference. In some cultural backgrounds the single pregnant student, though from an extended family, may be ostracised for religious or social reasons. The decisions made by a pregnant science student of any cultural background may tend to be similar. Despite the financial aid she may receive from government agencies, if any, she may delay the completion of the degree or a change from a science degree (which requires practical work) to a degree in humanities (which is easier to complete from an online University). It is likely her decision will result in the postponement of all future study. Only with a lot of support can a student in this predicament persevere with the study of science and eventually take up a science career. An article *When Scientists Choose Motherhood* (Williams & Ceci, 2012), concluded that "Our own findings as well as research by others show that the effect of children on women's academic careers is so remarkable that it eclipses other factors in contributing to women's underrepresentation in academic science" (p. 138).

As part of their traditional role in society, women are mothers and home builders and play a major and often a single role in bringing up children. This has a huge impact on their studies and career. Women who for similar reasons have postponed their studies may not pick up the same degree or course of study depending on their home situation and their need to have a career later in life. Child-rearing may take up the best part of their lives and their health, energy and focus may be different compared to the enthusiasm with which they first started a degree or career (Wolf- Wendel & Ward. 2006). Women who have married men who may be still completing their studies may take up a part time job not necessarily related to their science degree, to let their partner further his studies and career, because even in this 21st Century, the male is often

considered by many to be the bread winner whose career is of greater importance. Very few women put off having children till they reach all their career goals due to the ticking of the biological clock. With new techniques available in science, this may not be such a problem in the future, but one must always consider the unplanned pregnancies, and home situations, which cannot be foreseen at the start of a science degree or career. Furthermore, women, may interrupt their studies to look after sick parents or other sick family members, thus putting their own careers on hold (Misra, Lundquist, & Templer, 2010).

Women who have been successful and have a science a science career may decide to become part-time to be able to drop off and pick up children from school, thus restricting themselves from promotions which may be available to persons who can give up more time during the day and after hours to the demands of the job. These women who put their children first are thus not discriminated against by employers but have chosen to take up a lower profile job and balance it with family commitments. Some women choose career over children, but these would be a smaller proportion of the female population. In general, the probability for an interruption to her course of study or career journey is greater for a woman (Maher et al., 2004).

2.11 Conclusion.

Women, both in the past and near present, have overcome obstacles of prejudice based on their gender, to succeed and contribute to the field of science. Knowledge of their achievements in spite of all odds, will serve as a beacon of light to the present generation, to which the study participants belong. The literature discussed in the chapter explores the roles of the teachers, parents siblings, scientists and the media on science education. These factors have been introduced into the questionnaires designed by the researcher which will be discussed in detail in the consequent chapters. The role of the media and the use of technology in particular is of current importance to science education today. The interruptions to a science career for a woman as discussed is this chapter were related to her role as the primary carer for the family. In the present time this role has become less distinct with men becoming more flexible in accepting household duties and with online studies gaining popularity.

We can therefore conclude on a positive note realising that the present time offers ample opportunities for women in science.

Chapter 3

Methodology

"Even if we accept the (doubtful) proposition that categories are discovered, what we discover will depend in some degree on what we are looking for – just as Columbus could hardly have discovered America if he had not been looking for the Indies in the first place." (Dey, 1999, p. 104).

3.0 Overview

In this chapter the methodology of the longitudinal study is discussed in detail. The research design and the methods used for data collection and analysis are clearly represented, including the various research instruments such as the early attitude questionnaires, one-on-one interviews and online questionnaires. The process for the development of the scale items for the participant, teacher and parent questionnaires is illustrated and an overview of the participation selection is introduced.

3.1 Aim of this Study

The aim of this longitudinal study is to identify those factors which are deemed responsible for the perseverance of science study by female students. Their progress from secondary school to the end of the first science degree and start of a career has been recorded in the form of case studies. The study began with 16 students who had chosen science subjects either physics chemistry or biology or a combination of these, with the intention of continuing with a degree in science. From these 16 students eight were chosen as final participants for the study though they were of different ages and had commenced their university courses in different years. The eight case studies used for analysis present very strongly with perseverance in completing their science or science related courses. This study may help identify those factors which are of importance to the field of female graduate education and education in general.

3.2 Research Design

The research design chosen is based on the grounded theory (Charmaz, 2000) and case study method (Yin, 2009). The reason for this choice was based on the fact that a theoretical framework was required to be developed to show the progression of the participants as they chose their subjects and completed their courses in school and in university. In order to develop this framework the researcher set out to collect large amounts of unstructured textual material from formal and informal interviews and observations. Relevant information obtained from this data was used to develop theory.

This research design described in this chapter has been chosen because it applies best for this longitudinal study. The combination of methods used – the grounded theory and the case study method allow for greater flexibility in the collection and use of the data, and hence the emergent theory. The construct and internal validity are high and compensate for the lower scale of external validity due to the reduction of the initial cohort. The time spent on this longitudinal study and the accuracy of the data collected should add strength to the purpose of the study. In addition to these points, longitudinal studies are not as common as lateral studies and therefore add value to the field of science education.

The case study method involves cross analysis of selected case studies using the grounded theory to develop further theory. The data collection research design and emergent results are aided by the theory which becomes the driving force for final analysis and conclusions (Yin, 2009).

Grounded theory, first introduced to the world by Glaser and Strauss in 1967 in a book *The Discovery of the Grounded Theory,* captivated social scientists at that time. Since then the theory had evolved mainly into two theories- Glaserian Theoretical Sensitivity (1978) and Straussian Qualitative Analysis (1987) and has further evolved to variations of the original. Clarke (2005) who worked with Strauss developed "Situational analysis" which offers techniques to incorporate diverse data sources. In her book *Situational Analysis: Grounded Theory after the Postmodern Turn,* she explains the systematic collection and evaluation of data aims to identify internal and external forces that may influence performance and to assess the factors responsible for this performance. Charmaz, one of the co-authors of, *Developing Grounded*

Theory: The Second Generation (Morse et al., 2009), while discussing the grounded theory methods, suggests that one is required to go deeper into the data collection and connect this information with the large concerns rather than do a shallow analysis. The basic features of grounded theory are summarised as follows:

> We gather data, compare them, remain open to all possible theoretical understandings of the data, and develop tentative interpretations about these data through our codes and nascent categories. Then we go back to the field and gather more data to check and refine our categories. (Charmaz & Henwood as cited in Willig, 2013, p. 80).

The initial step taken in this study was to identify the area of interest, which in this case are the students who have chosen to take up science in Years 11 and 12 with the intention of studying science in university. Students were chosen from the school in which the researcher worked for 22 years, consent and participation forms were completed by all students who had agreed to be part of this study (see Appendix A). At the start of the study these students were below 18 years and so their parents gave permission as well. Teachers who were interviewed did so willingly and with the intention that their answers and contributions would benefit science research and therefore science education.

The next step was to collect the data. In keeping with the grounded theory plan the data can be a mixture of qualitative and quantitative and can be in the form of observation, discussion written questionnaires and one-on-one interviews. This information also included examination results and test scores. Details about participants were obtained by accessing examination records and by obtaining teacher and parent responses to surveys. The researcher has had access with permission to use the student records for the Year 10 and Year 12 examinations. Students had one-on-one discussions about their interests and attitudes to science and completed the science attitude questionnaires given to them by the researcher during their free periods. They were not taken out of class and therefore did not miss any school work because of completing the questionnaires or interviews. Raw data were collected and coded (see Appendix B). All the students had a code name and the questionnaires were ordered and coded as well. The names of the teachers and parents involved were also coded.

Data such as early science- related questionnaire responses from participants who had been eliminated from the study were also coded and stored in a safe place.

The reduction of participants from the study took place for various reasons (see Figure 3.1). Some changed their degrees to study other non- science subjects, while others just lost contact or moved to other states. This reduction in the number of participants led to the reorganisation of data and coding which became more selective. The remaining eight case studies (see Appendix B) were given pseudonyms by the researcher and numbers from one to eight. Specific and detailed collection of information related to their academic journey in senior school and university became the core of this research.

When combining methods like case study and grounded theory, "utmost care must be exercised to ensure that the canons of case study research do not distort true emergence for theory generation" (Glaser, 1998 pp. 40-2). For example, Yin (1994, p. 28) states 'theory development prior to the collection of any case study data is an essential step in doing case studies.'

The literature review of women in science gave a broad overview of the role women have played in the past present and will in the future. It also gave hard facts about the influence of the socio-economic status, gender, and cultural background on the study of science. In addition to this, the review mentioned the influence of primary teachers, secondary teachers and parents, on the career of a female student, set out to work in the field of science in the 21st century.

When grounded theory is used the literature, review is usually written after some emergent theory. In this study there is, as mentioned earlier, a broad literature review at the start of this study which not only gives an overview but also acts as a hypothesis. Questions asked by the researcher at the end of the review may or may not be answered at the end. In addition to the earlier literature review there are on-going literature reviews with the relevant case study links to the research questions and a concluding review as well which will specify the theory which emerges. At this stage, when the theory becomes complex and detailed the researcher is considered to have developed a substantive theory. Substantive theories can be classified as middle-range theories and are modifiable and relevant to the study (Glaser & Strauss, 1967). Table 3.1 gives an overview of the thesis structure and research design.

Table 3.1 *Overview of the Thesis Structure and Research Design*

Thesis structure and research design
Background and introduction
Literature review - women in science facts and hypothetical questions
Methodology
Grounded Theory Method
Observations, interviews, questionnaires
School and university results
Case Study Method
Literature review of academic progress in response to the three objectives
Concluding analysis, limitations and recommendations

3.3 Participants and Settings

Students

The students of Years 11 and 12 in an independent girls' school in Sydney's north-west were the participants of this study. They had attended the 'Subject Choice Information Night" held in the school for students of Year 10. They had attended this information night with their parents, who were able to ask the teachers who were present and the director of studies any questions regarding the choice of subjects. The school offered all three science subjects at that time – physics, chemistry and biology.

Sixteen students who were participating in this study were from different years but relatively close together- completing their Higher School Certificate during the years 2006-2010. This examination is an external one organised by the New South Wales Standards Authority (NESA), and hence determines entry into the universities in the state. The students had at least one science subject for the Higher School Certificate.

These students went on to start science degrees. Some of them completed the degrees while others made changes. The eight case studies used for this study from the original 16 were chosen by the researcher because they best demonstrated the factors which showed perseverance in science education. The participants were all known to the

researcher and most of the interviews were conducted in school while the use of questionnaires allowed for further information and data to be collected. Figure 3.1 gives an overview of the participant selection with a timeline.

Overview of Participant Selection with Timeline		
Participants 1-16	Commencement for collection of data mid 2007-2013 using school reports and University reports (Grounded Theory)	Time 6 years
	TOSRA administered to identify science attitudes.	16 questionnaires administered over a period of 4 years.
	Observation of participants in the science classroom to identify interests and attitudes.	As all the 16 participants were in Years 11 and 12 in different years. Observations made over 5 years.
	One on one interviews with participants	As all the 16 participants were in Years 11 and 12 in different years. Interviews over 5 years.
	Online Questionnaires and scales developed from data collection and administered to all participants	As all participants were in University in different years. This data collection took a period of 6 years.
Participants 1-8	Completed science or science- related degrees, completed post graduate studies and obtained jobs. *Formed the final cohort for this study*	
Participants 9-16	Participant 10, 11 and 13 dropped science in university.	
	Participants 9 14 and 15 lost contact with researcher.	
	Participant 12 and 16 did not want to continue to be part of the study.	
	Original Participant 6 replaced by a new Participant 6 (2013).	

Figure 3.1 *Overview of participant selection with a timeline*

Other Participants - Teachers, Director of Studies, Parents

The other participants in this study were the science teachers who were teaching these students in the years 2005-2010 in school. In addition to this the then director of studies made considerable contributions of information and data with respect to Year 10 and later Year 12 examination results. She also doubled up as a career advisor as well and being a science teacher and was able in her position to give specific and practical advice for future science study and possible science careers. Parents played a role in answering basic questionnaires, phone interviews as well as face-to-face interviews.

3.4 Instrumentation

Reasons for Chosen Instrumentation

What is the attitude of the present-day female students towards science and science education? What methods can be used to establish attitudes of students towards science education? This is the first objective. Fraser (1994) discussed the associations that have been established between the science classroom environment and a variety of student outcomes. The researcher started making notes for each participant very early in the study when classroom observations were being made. The observer was looking for student interest and attitudes and wanted to see how students participated in the school classroom and laboratory, and the effect of the environment on them. The initial science attitude questionnaire which was given to the 16 participants was the Test of Science Related Attitudes (TOSRA) (Fraser 1981).

Test of Science Related Attitudes TOSRA

This instrument (Fraser, 1981), administered to all 16 students contained 70 statements about attitudes to science (see Appendix C). In this questionnaire there were no "right" or "wrong" answers. The eight students whose case studies have been documented contributed information towards their early science-related attitudes. The students had to number the statements as follows 1. Strongly Disagree (SD), 2. Disagree (D), 3. Uncertain (U), 4. Agree (A), 5. Strongly Agree (SA). Both researchers and teachers can use TOSRA to obtain information about the science-related attitudes of students. Individual tests as well as whole class tests may be used depending on the purpose of the study. The period over which the tests can be monitored may also vary to identify attitudes at a moment in time or changes in attitudes over a period. Details for each candidate's scores for all seven items and the average of the 16 students is recorded discussed and analysed in Chapter 4. The uses of TOSRA as stated in the Test of Science -Related Attitudes Handbook are:

> A major advantage that TOSRA has over some other science attitude tests is that it yields a separate score for a number of distinct attitudinal aims instead of a single overall score. This makes it possible to obtain a *profile* of attitude scores for groups of students (Fraser, 1981, p. 6).

The students' Year 10 examination results were scrutinised before TOSRA was administrated. Some students were chosen based on recommendations by their science teachers who felt that they would be suitable candidates. Scoring methods are in Appendix C and scores in Chapter 4.

Table 3.2 *TOSRA: Description of Scales and Sample Items*

Scale name	Description of scale	Sample items
Social implications of Science(S)	Manifestation of favourable attitudes towards science and scientists	Public money spent on science in the last few years has been used wisely
Normality of Scientists (N)	Manifestation of favourable attitudes towards science and scientists	Scientists are less friendly than other people.
Attitude to Scientific Inquiry (I)	Acceptance of scientific inquiry as a way of thought	I would prefer to find out why something happens by doing an experiment than by being told.
Adoption of Scientific Attitudes (A)	Adoption of 'scientific attitudes'	I dislike repeating experiments to check that I get the same results
Enjoyment of Science Lessons (E)	Enjoyment of science learning experiences	School should have more science lessons each week
Leisure Interest in Science (L)	Development of interest in science and science-related activities	I get bored when watching science programs on TV at home
Career Interest in Science (C)	Development of interest in pursuing a career in science	When I leave school, I would like to work with people who make discoveries in science.

(Adapted from Test of Science-Related Attitudes' Handbook) (Fraser, 1981)

Table 3.3 *Reliability of TOSRA scales (n=16)*

Scale	No of items	Example Item	Cronbach alpha Reliability
Social Implications of Science	10	Science helps to make life better.	.84
Normality of Scientists	10	If you met a scientist, he would probably look like anyone else you might meet.	.87
Attitude to Scientific Inquiry	10	Doing experiments is not as good as finding out information from teachers	.73
Adoption of Scientific Attitude	10	In science experiments, I like to use new methods which I have not used before.	.84
Enjoyment of Science Lessons	10	Science is one of the most interesting school subjects.	.86
Leisure Interest in Science	10	I would enjoy having a job in a science laboratory during my school holidays.	.82
Career Interest in Science	10	A job as a scientist would be interesting.	.87

Scores for each scale totalled 50 as a maximum. Scores of 0- 25 were considered a low score, 26- 35 an average score and 36-50 a high score for each item.

Additional Questionnaires.

The development of the questions for additional questionnaires was based on the literature review. It sought to research the influence of the home environment, parents, and teachers on the students. The questionnaires also sought to find the influence of scientists, role models, the government and the media, on the students decision to study and persevere with science eduation

The researcher used additional questionnaires to obtain information from the participants, about their attitudes towards science and the external influences on their academic journey. Information was also obtained from teachers and parents through specific questionnaires.

The Participant at University questionnaire (PAU 1) was given to the eight students while they were in university. The researcher developed eight questions given to the participants in one-on-one interviews, by email and phone conversations. These interviews were conducted at the start of the undergraduate degree for most of the participants and included the original 16 students. Some students answered these questions after they had completed the first degree, so they were recounting their experiences which were still quite fresh in their memories. Student responses to these questions were written down. These data were used to develop the background of each participant and served as the introduction to the participant history. Original memos of some responses to this questionnaire are in Appendix D. Table 3.3 reproduces these questions and the detailed account of these responses has been developed into the literary structure of the case studies.

Table 3.4 *Participant at University Questionnaire (PAU 1)*

No	Question
1	What are the factors which caused you to take up a science degree?
2	What difficulties, if any, did you experience while doing this undergraduate degree?
3	What strategies did you use to overcome these difficulties?
4	Did family support play a role in motivating you to study?
5	Can you identify any reasons why you may have not experienced any difficulties while doing this course?
6	Did you take part in extracurricular activities while doing this degree? If so name these activities.
7	Did you work while studying? Give details of working hours.
8	Did you travel overseas while studying? Give the duration of travel.

These questions and their responses helped to lay the foundations to the eight case studies. Some participants were able to have a discussion with the researcher and

because of these conversations their responses are more detailed compared to others who answered by email. The remaining questionnaires asked specific questions to build upon the foundations of the case studies. The theory already developed by the researcher based on the participant observation, discussion with teachers, one-on-one conversations with the participants and memos from Questionnaire PAU 1, led to the development of scale items and questions. Common scales were considered, and questions written to be categorised into these existing scales.

Development of Scale Items for Consequent Questionnaires.

The development of relevant scale items for consequent questionnaires was based on large amounts of information gathered from specific and different sources over five years and evolved in the following way:

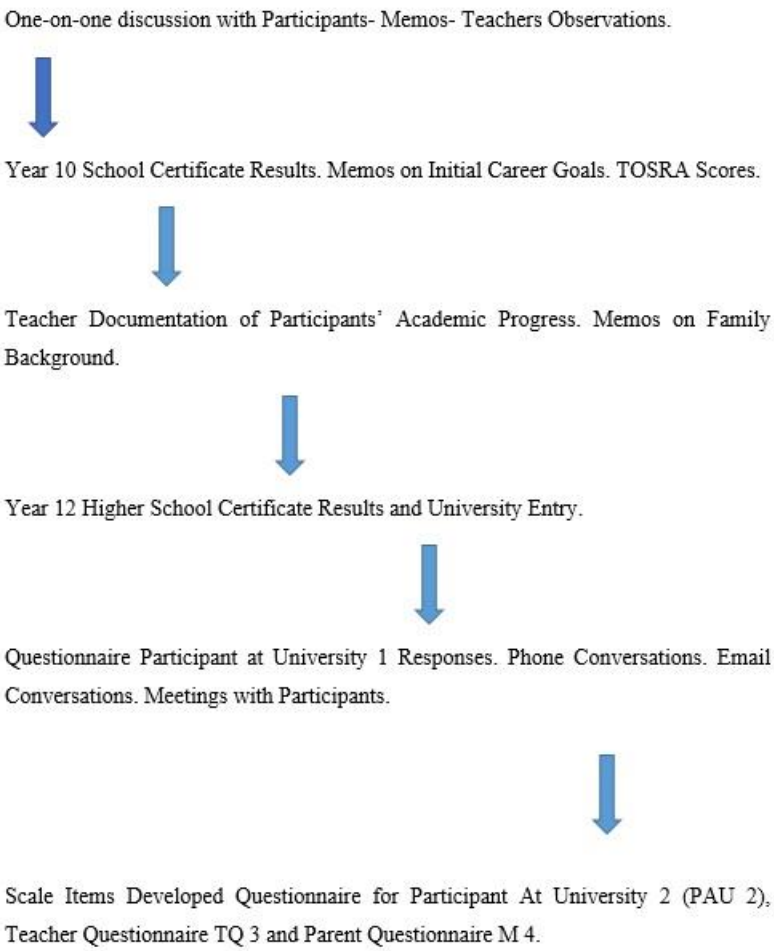


Figure 3.2 *Information gathered over five years for developing the questionnaires, PAU 2, TQ 3 and M 4.*

Common Scale Items developed such as Teacher Influence, Career, Family Support, and Personal Traits, contained different questions for participants, teachers and mothers of participants. Some questions were similar to elicit the same information from different sources and thus confirm the emergent theory. These developments were discussed and agreed upon with the author' supervisor in an interactive manner until consensus was reached.

Participant at University Questionnaire (PAU 2)

Twenty-one questions were classified under the seven items Teacher/Mentor, Career, Family, Friends/Respect, Personal traits, Scientists and Government. Participants were able to answer these questions online by ticking under the five scales numbered 1- 5 (see Appendix E). Scores of 1, 2, 3, 4 and 5 were awarded for responses Strongly Disagree, Disagree, Undecided, Agree and Strongly Agree, respectively for all 21 questions. Raw scores and percentage scores are recorded in Table 6.1 and in Figures 6.1-6.3.

Weak, mediocre and strong scores were linked to the percentage scores rather than the raw scores. Percentage scores allowed a fair comparison. The same method was used for the remaining questionnaires. A score of 80% and above would be considered a strong score. Similarly a score of less than 50% would be considered a weak score and 50-80 % a mediocre score.

Table 3.5 *Description of Scale Items for Questionnaire PAU 2 (see Appendix E)*

Scale item	Description of scale item	Sample item
Teachers/ Mentors	Identification of the influence of teachers and mentors on student's decisions	I have been influenced by my teachers and career advisors to take up a science/ science related degree
Career	Employment pressures on subject choices made for school and university	I feel that a Science degree is far better for the job market than a non -Science degree.
Family	Impact of parents and siblings on student choices and academic progress	My Mother's managerial skills at home/work outside the home, encouraged me to better myself using the opportunities available.
Friends/ Respect	Influence of friends on student's study habits and academic progress	I worked with my friends as a team studying together in the library, sharing resources and experiences.
Personal Traits	Identification of student's strengths	I worked very hard and gave up free time to work in the library focusing on assignments and examinations.
Scientists	Impact of leading scientists on decisions to study science	The leading scientist/ scientists in the country/ overseas served as my role models
Government	Influence of government decisions on education	Science research will benefit further if the Australian Government makes it a priority.

Teacher: Questionnaire (TQ 3)

Teachers were able to answer this questionnaire online. Four teachers responded giving information about seven of the eight participants. There were 25 questions classified under the five items Teacher/Mentor, Career, Family influence, Friends/Respect, Personal traits. Scores of 1 2 3 4 and 5 were awarded for responses Strongly Disagree, Disagree, Undecided, Agree and Strongly Disagree, respectively for positive questions and in the reverse for negative questions. Raw scores are recorded in Figures 6.4-6.6, and Table 6.2 in Chapter 6.

Table 3.6 *Description of Scale Items for Teacher Questionnaire TQ 3 (see Appendix F)*

Scale Item	Description of scale	Sample item
Teachers /Mentors/Role Models	Teachers observation of their own positive influence and those of mentors and role models on students.	Female role models such as scientists, academics and politicians may have influenced this student to persevere and complete her degree
Career Opportunities	Teachers identification of career influence on students	This student was motivated to take up science in Years 11 and 12 with the hope of receiving good results, taking up a science degree in university and obtaining a good job
Family Influence	Teachers observation of the influence of the family on the student's decisions	This student was strongly supported and encouraged by her family members
Friends	Teachers observation of the influence of friends on the student.	Friends in the same university have helped this student to persevere with the study of Science.
Personal Traits	Teachers observation of student's character	This student was confident, and this personal trait has helped her to succeed in completing her degree.

Note: The four teachers average score on each item for each participant was used for calculations and graphical representations

Participant's Mother: Questionnaire (M 4)

Mothers of the participants were given this questionnaire online. The questionnaire consisted of 24 questions which could be classified under four items. The items were Family support, Balance/ Stress, Teacher/ Education and Careers. Questions 5, 6 and 7 elicited information about the mother's work but were not classified under any item and did not carry scores. Scores of 1, 2, 3, 4 and 5 were awarded for responses Strongly Disagree, Disagree, Undecided, Agree and Strongly Disagree, respectively for positive questions and in the reverse order for negative questions. Raw scores and percentage scores are recorded in Figures 6.7-6.9 and in Chapter 6. (see Appendix G).

Table 3.7 *Description of Scale Items for Mother of Participant Questionnaire M 4 (see Appendix G)*

Scale Item	Description of scale	Sample item
Family Support	Identification of parental support	During the Higher School Certificate and University examination periods I gave my daughter extra emotional support
Balance/ Stress	Parental observation of the daughter's ability to balance study and everyday life	My daughter was confident and able to organise her studies and her recreation/ part time work well
Teachers/ Education System	Manifestation of parental attitudes towards the education system and teachers.	I felt that my daughter had received adequate information in school about science degrees and science careers
Careers	Parental recognition of career influence and the job market requirements	I feel that though my daughter has succeeded in completing her degree, there will not be a suitable career for her in Sydney

Table 3.8 *Summary of the Additional Questionnaires used for obtaining Information about the Participants Based on Common Scale Items*

Questionnaire Name	Description of Questionnaire
Participant at University (PAU 1) (Appendix D- Memos)	Interview with eight questions. Notes and memos. Relevant notes simplified to include specific facts. Literature review in Chapter 3 (Introduction of participants).
Participant at University (PAU 2) (Appendix E)	Online questionnaire with 21 questions and seven scale items Questions with positive scoring included. Method of scoring in Appendix (E). Scores in Chapter 5. Literature reviews in Chapters 5 and 6.
School Teachers (TQ 3) (Appendix F)	Online questionnaire with 25 questions and five scale items. Questions with positive and negative scoring included. Mean of four teacher score used for calculations and graphical representation. Method of scoring in Appendix (F). Scores in Chapter 6. Literature reviews in Chapter 6.
Participant's Mother (M 4) (Appendix G)	Online questionnaire with 24 questions and four scale items. Questions with positive and negative scoring included. Three questions not included in score but used for data. Method of scoring in Appendix (G). Scores in Chapter 6. Literature reviews in Chapter 6
Participant at University PAU 3 (Appendix H)	Interview with six questions. Questions designed to obtain further information about friends at university and their influence on the participants. Literature summary in Chapter 6.

3.5 Research Procedures

Decisions about the selection of research participants

The study began with observations made in the Year 10 classroom and later in the science laboratory. Students were carrying out practical work based on first hand investigations in physics, chemistry and biology. These first-hand investigations were part of the Preliminary Course set by the New South Wales Education Standards Authority (NESA) formerly known as the Board of Studies (BOSTES). The researcher made notes on student participation and made up a list of possible students who would probably be participants in the study

Ethical procedures and considerations

Once the researcher had completed the Ethics paperwork prior to the commencement of this study (see Appendix A), she discussed with teachers relevant to the subject, the appropriateness of the students selected and the validity of the procedure. The students were given a Consent and Participation form (see Appendix J) to fill in and to get signed by their parents if they were under eighteen at that time. Once these forms were filled in and signed the researcher coded them and placed them in a safe place as required by the University.

The students chosen to participate in this study were around 17-18 years old at the start of the study. They were willing to take part in the study and were told that they could choose to leave at any time. Some were very eager to know how they could help the researcher and had to be reminded that there were no right or wrong answers to the questionnaires. They were encouraged to be as truthful as possible. They all filled in the consent and participation forms and their parents signed the forms as well. As time progressed the students had become young adults and did not require any further signature to the information they were imparting to the researcher, both with the verbal discussions and the exchange of examination data and university transcripts.

Year 10 and Year 12 examination results for science were obtained with permission from the students, their parents, principal of the school and the director of studies. All agreed that the parting of this information was for the sole purpose of research in the field of science education. The researcher reminded the students that they did not have to give details of their university transcripts if they did not want to at any stage in this longitudinal study.

At times, the researcher did feel that if any participant was not as willing as they had been earlier to be part of the data collection, they could be removed from the study. However, the removal of certain case studies was done solely because their information and data did not directly benefit the study and not because the participants had a change of mind. The researcher did find that answers to questions were a bit more guarded as the students matured and assumed that this is a natural result of departing from childhood.

Completion of the written instruments

Students, now 16 in number, were given the Test of Science Related Attitudes (TOSRA). Some students took the questionnaire home to complete while others completed this questionnaire in their free periods at school. The researcher discussed the implications of the need to write their own opinion and not to write what they thought the researcher wanted to know (or would like). Honesty in answering the question was reinforced by the fact that the students were told that their names would not be disclosed, and they were going to be coded.

Interviews

The researcher interviewed the director of studies and the relevant subject teachers and wrote notes about each student. As all the students were not in the same year the researcher followed this pattern in the next few years for each participant as soon as they reached Year 11.

Prolonged contact

While the students were in Year 12 and getting organised to do the Higher School Certificate, the researcher did not ask them to participate in any discussion, nor fill in any questionnaire, thus respecting the students need to focus on the final year of schooling. However, after the examination and close to the end of January when many students had been accepted into a course at University, the researcher then contacted the participants through email and phone. This was an important time as with degree selection, the participants were able to make clear to the researcher if they were going to study science in the next 3-5 years.

The researcher noted that some participants were doing a degree of varying length while others were still in Years 11 and 12. The researcher conducted some interviews with students who had already finished two years of their degree and started writing

their case studies in the form of a journey. Unfortunately, some TOSRA tests were given to the participants after they had finished school due to changes within the original cohort. This has been discussed as a limitation to the study in Chapter 7.

3.6 Data Processing and Analysis

Data were collected through the questionnaires, school and university results and through interviews. Once the eight participants were selected, individual literature chapters were written for each participant. These eight chapters served as a foundation for the main body of the thesis. Information about the eight participants has been narrowed down to information that is specific to the three objectives. Chapters 4 5 and 6 have addressed these three objectives using the vast amount of information collected and the reader will get to know the participants gradually and in relevance to the objective questions. In chapter 7, there is a cross-case analysis of the eight case studies and the relevant theory which has emerged is identified.

The study used multiple participants and later reduced the number of participants to eight. These eight case studies could be multiple case studies. There are advantages of using multiple case studies. The evidence is more compelling, and the overall study is considered more robust than single case studies. The vast amount of data collected is directly from the participants or their teachers and family. The disadvantages of using this method are that multiple case studies require extensive time and resources. Developing theory could be complex, thus resulting in the elimination of large amount of data which initially took a long time to collect and process

The summary (see Figure 3.3)indicates how the researcher has followed the structure of the grounded theory and case studies and has used some of these methods quite successfully to carry out and complete the longitudinal study.

Construct Validity
Concepts being studied are operationalized and measured correctly (Yin, 2009) Initial selection of participants based on interviews, early science attitude questionnaires, and subject choice in Year 11/12 Collections of data based on school and university examinations
Internal Validity
Establish a causal relationship and distinguish spurious relationships (Yin, 2009) Discussions questionnaires, interviews, teacher and parent information Elimination of surplus data and data not directly related to the study
External Validity
Establish a domain towards which the study's findings can be generalised (Yin 2009) Selection of eight case studies for analysis. Development of Scale Items for Participant Teacher and Parent Questionnaires. Emergent theory-reliable due to cross case analysis and multiple independent data sources
Reliability
Demonstrating that the operations of a study-such as the data collection procedures-can be repeated, with the same results (Yin 2009) Collection of results from questionnaires responses, school examinations and university transcripts. Linking the results to produce reliable theory

Figure 3.3 *Using theory from Yin, (2009) (Case Study Research Design and Method) and utilization of this theory in the present study.*

The function of multiple case studies is to generate explanations which can be analysed and tested (Miles & Huberman, 1994). For complex real-life situations multiple case studies or cross-case studies may be used. Yin (1994) advocates two general strategies for analysing single or multiple case studies.

The primary strategy uses theoretical propositions that guide the study and data collection on specific data. The researcher has used this strategy to guide and collect data specific to research question "What factors are responsible for the perseverance of science study" narrowing the participants down to female student who have chosen science subjects for Years 11 and 12. In addition to this questionnaires were directed

towards collecting data based on the three objectives- science attitudes, examination results, and influential factors.

The second strategy suggested by Yin (2009) develops a descriptive framework for organising the case study data. Different modes of analysis may be used to find links and patterns for the emergent theory. The researcher has attempted to apply this strategy as well in the second part of the study, finding patterns which were direct and simple from the eight case studies chosen for cross analysis. Different outcomes may be explained with theory using a general analytical strategy. With the use of multi-case sampling (Miles & Huberman, 1994) and consequently logical replication (Yin, 1994) validity can be improved.

The four tests for judging the quality of research design have been identified by Yin (2009) as construct, internal and external validity and reliability, and by Denzin and Lincoln (1998) as internal and external validity, reliability and objectivity. The researcher has attempted to apply this strategy as well in the second part of the study, finding patterns which were direct and simple from the eight case studies chosen for cross analysis as shown in Figure 3.1.

Validity reflects the accuracy and authenticity of the findings. By making multiple group comparisons and by using a wide range of data, validity can be improved (Miles & Huberman, 1994). The researcher had direct contact with the 16 original participants and maintained contact through discussions, questionnaires and interview.

Internal validity is used in explanatory studies through identifying causal relationships where one condition leads to another (Yin, 1994). The identification of patterns or themes can lead to a systematic understanding of the findings of the study and in turn can lead to verifying conclusions (Miles & Huberman, 1994). Similarly, the literature from cross-case studies can yield patterns of similarities and differences within groups and between groups (Eisenhardt, 1989). Comparison of theory to data allows constructs to be identified from multiple sources of information to provide construct validity. The researcher looked for patterns when examining the journey undertaken by the participants in the choice and study of a science subject in school and in university. Comparison and analysis between the case studies strengthened the internal validity of the study.

External validity requires that the findings and theory which emerge may be directed towards a domain. Campbell and Stanley (1966) proposed the commonly accepted definition of external validity, whether causal relationships can be generalized to different measures, persons, settings, and times. Barry (2005), has pointed out the disadvantages of longitudinal studies, due to systematic attrition when participants drop out of a study for various reasons and thus affect the external validity. While this cannot be avoided, it should be reported by the person conducting the study. Other research has suggested that the participants who leave a study will affect the external and internal validity. If they are like each other but not representative of those who remain in the group, the external validity is weakened. This was not the case in this study as the eight participants who were not included in the final study, scored very similar responses in the TOSRA instrument (see Appendix C) and from memos retained by the researcher, (see Appendix D) had similar attitudes while they were in school.

3.7 Conclusion

Qualitative researchers often encounter a difficult problem when trying to decide what to write about their findings (Corbin, & Strauss, 2008). The source of the problem is the complex body of data generated during the entire research process. The big questions are: "What of all this analysis should be included? How can I compress all of these findings into a couple of chapters?" (p. 281). Initially this study contained 16 chapters in its raw form and each participant had a separate chapter. This thesis has since then been reduced to eight chapters and the initial eight chapters devoted to each candidate's academic journey, have been rewritten under the three research objectives.

In the process of evaluation Charmaz (2006) suggests a list of criteria for evaluating constructivists' grounded theory. She breaks her criteria into four categories. These are credibility, originality, resonance and usefulness.

> For example, under credibility she says, "Do the categories cover a wide range of empirical observations? Are there strong logical links between the gathered data and your argument and analysis?" Under originality she asks, "Are your categories fresh? Do they offer new insights?" Under resonance she says, "Do the categories portray the fullness of the studied experience?" And under

usefulness she says, “Does your analysis offer interpretations that people can use in their everyday worlds? (pp. 182-183).

These criteria acted as a guiding light towards this research. These criteria, in combination with suggestions by Corbin and Strauss (2008) for judging the quality of research have been immensely useful. Corbin and Strauss classify criteria under the ten titles of fit, applicability, concepts, contextualization of concepts, logic, depth, variation, creativity, sensitivity, and evidence of memos, and states ‘‘Readers are advised not to worry needlessly about every little facet of analysis. Sometimes a researcher has to use common sense and not get caught up worrying about what is the right or the wrong way’’ (p. 327).

The researcher has thus used “common sense” to utilize the grounded theory and the case study literature to identify the emergent theory successfully.

CHAPTER 4

INITIAL INTERESTS AND ATTITUDES TOWARDS SCIENCE

"Remember to look up at the stars and not down at your feet. Try to make sense of what you see and wonder about what makes the universe exist. Be curious." Stephen Hawking. (Hawking, 2012) (Recorded speech for his 70th Birthday symposium).

4.0 Overview

The first objective was to determine the interests and attitudes of secondary female students towards science education. The eight case studies chosen from the initial 16 students are used to answer the research questions related to this objective. Information has been obtained from questionnaires TOSRA, PAU 1 and from one-on-one discussions with science teachers and the participants themselves.

The research questions related to the first objective are:

1a: Who are the potential science students who may take science in university and have science careers?

1b: What are the student's attitudes and interests in science and science careers?

1c: What are the sources of the students' interest in science in school?

4.1 Research Question 1a - Who are the students who may take science in university and have science careers?

Except for one student, all were from the same school. They were therefore, subject to the same conditions at school and taught by the same teachers. The learning environment was more similar than it was different and served as a constant factor.

During the period of this study the school was very strong in the teaching of science and students were encouraged to take up at least one science subject in Year 11. Practical experiments were conducted in the laboratory and students were expected to document each experiment as well as possible. Graphs, tables, diagrams and photos of experiments were used, and each experiment was marked and graded by the teachers. The school's science facilities ensured that the necessary apparatus was available and made sure that risk assessments were written up and carried out. The school students

took part in the events of special science week activities and each class undertook some special science program or activity including games with their class' science teacher. Each year the science department met and planned out the events for this week. Moreover, leadership roles were given to some Year 11 science students who played an active role in demonstrating interesting experiments to the Year 6 students and their teachers, to motivate and foster an interest in science. Therefore, in this school, students arrived in Year 7 (the first year of secondary school) with some added encouragement to be more involved in science activities and to learn from them. Table 4.1 summarises the science subjects and mathematics level of the 16 students in Years 11 and 12.

The researcher held one-on-one interviews with the 16 students who were chosen with the help of recommendations from their science and mathematics teachers to gain information about their potential science careers. Students were given the TOSRA instrument to answer, for some students this occurred in Year 10 and for others in Years 11 and 12.

Table 4.1 *Initial Participant Science Subjects and Mathematics Level in Years 11 and 12 (n=16)*

Participant/	Final Year	Science Subjects	Mathematics Level
1	2006	Chemistry Biology	Advanced Mathematics
2	2007	Physics	Advanced Mathematics
3	2009	Physics Chemistry	Advanced Mathematics/ Extension 1
4	2008	Chemistry	Advanced Mathematics/ Extension 1
5	2008	Chemistry Biology	Advanced Mathematics
6	2006	Chemistry Physics	Advanced Mathematics
7	2007	Biology	Advanced Mathematics
8	2010	Chemistry, Biology	Advanced Mathematics
9	2007	Physics Chemistry	Advanced Mathematics
10	2006	Physics Chemistry	Advanced Mathematics
11	2006	Physics Chemistry	Advanced Mathematics
12	2010	Physics	Advanced Mathematics
13	2008	Physics Chemistry	Advanced Mathematics
14	2008	Physics Chemistry	Advanced Mathematics/ Extension 1
15	2011	Physics Biology	Advanced Mathematics
16	2011	Physics Chemistry	Advanced Mathematics/ Extension 1

4.2 Research Question 1b - What are the student' attitudes and interests in science and science careers?

Students' interest in science may stem from external sources such as experiments demonstrated in the laboratory, television documentaries with strong and graphic audios and visuals, and from parental involvement with a science-based career (Emerson, Fear, Fox, & Sanders, 2012). Monetary gains from a successful career may also spur on older students to take up a science subject in school.

In the state of New South Wales, mathematics and science were not compulsory subjects for Year 11 and 12 students during the period of this study. The system of education therefore did not compel any student to study science or mathematics at a

level higher than Year 10. A report by Wilson and Mack (2013) shows a trend of decline in mathematics and science from 2001-2013 in New South Wales. As there are many more exciting and easier subjects, it is important to discover why students should decide to take up either science or mathematics disciplines. It is true that student interest in science should start from primary years and then be reinforced in the secondary school. A report called *Shape of Australian Curriculum: Science* (2009*)* clearly states "Learning about science is a cumulative process that begins in early childhood and continues throughout schooling" (p. 4). Therefore, for students to willingly choose a science subject, great care and interest should be taken to foster students' consistent and continued involvement in the study of science. This goal calls for a school science department to have a vision and direction towards this mission of encouraging young minds to wonder about and to learn and love science during their school years. In addition to this, female students should be encouraged to study both mathematics and science if possible at school level and realise that they have equal opportunities to do so (Baker, 2016).

The students in this study were interviewed individually to obtain some knowledge and data about their general interests and attitudes towards science and science careers. Students met with the interviewer/researcher during their free periods. While they were very motivated to give their own opinions to various questions, some students had set very high goals for themselves.

The following questions were asked as an initial interview

1. Why do you want to take up a science subject for the Higher School Certificate examination?
2. Would you consider studying science in university?

Table 4.2 *Initial Responses for 16 Participants for Interview Question 1*

Question 1	Case	Response
Why do you want to take up a science subject for the Higher School Certificate examination?	1	Love for chemistry
	2	Interested in the environment
	3	Love for mathematics and science
	4	Would like to take up medicine
	5	Would like to become a Vet and so needs to study science
	6	Love for science
	7	Finds science interesting
	8	Love for biology
	9	Do not like humanities subjects
	10	Love for science
	11	Would like to become a doctor
	12	Love for science
	13	Love for science and its application to life
	14	Would like to become a science or mathematics teacher
	15	Love biology and would like to study this subject
	16	Love mathematics and science

From these early responses, most of the participants showed that they had a love for science and some idea that they would require a science subject for their future career, even though many did not have a definite career in mind. Students responded to the questions with answers that were both interesting and varied. The dream of being a doctor, engineer, vet or optometrist did cause some to take up science. One student had a love for chemistry and "was fascinated by forensic chemistry" saying that her interest was initiated by the TV series NCIS and other similar dramas involving the use of DNA tests, mass spectrographs and their function in detecting criminals and solving cold cases. Another student said, "My Dad is an optometrist and I would love to do the same even though I am a girl". Hence this love or interest in science caused these students to persevere in Years 11 and 12. Another student's love for animals, especially horses, led her to think of a career as a veterinary doctor.

It is interesting to note that at this stage (and will be evident in future chapters) many of these initial responses became realities not just for participants (1-8) who had formed the main study but also for the remaining eight (9-16) who did not. From These 16 participants have produced two doctors, one optometrist, one occupational therapist, a science teacher and deputy head of science, a mathematics teacher, an analyst and a finance manager. There are others who may have fulfilled their initial dreams but have lost contact with the researcher. Table 4.3 presents the responses for Question 2.

Table 4.3 *Initial Responses for 16 Participants for Interview Question 2*

Question 2	Case Study	Responses
	1	Would like to study science and mathematics and become a doctor.
	2	I am interested in engineering and the environment.
	3	I would like to be an optometrist like my father.
Would you consider studying science in university?	4	I would like to become a doctor and will take up science or medicine.
	5	I would like to be a vet, so I will study science.
	6	I am not sure but may take up science.
	7	I would like to study science but am not sure about a career.
	8	I would like to become an occupational therapist.
	9	I am not sure but may take up engineering.
	10	I would like to become a science teacher.
	11	I would like to study medicine and become a doctor.
	12	I am interested in space and astronomy.
	13	I would like to study biology and do research on diseases.
	14	I am interested in a science or mathematical career.
	15	I would study marine biology.
	16	I would like to become a mathematics teacher or an accountant.

Participants' Initial Goals

The participants who formed the study are numbered 1- 8 and their attitudes towards science and science careers are detailed in the next few paragraphs.

Table 4.4 *Participant Overview (Participants 1-8 as in Table 4.1)*

Participant	Name for Study	Family members including Parents	School Location (all girls only)
1	Jennifer	4	North West Sydney
2	Angela	5	North West Sydney
3	Anita	11	North West Sydney
4	Rita	11	North West Sydney
5	Megan	4	North West Sydney
6	Charlotte	4	South West Sydney*
7	Nikolina	8	North West Sydney
8	Xanthe	5	North West Sydney

Introduction of Participants

The eight participants chosen for the study were given pseudo names and numbers 1-8. The participant numbered 6 (Charlotte) replaced the original participant 6. Based on information obtained from discussion with teachers and responses to questionnaire-Participant at University (PAU 1) (Table 3.4), the literature for the case studies was organised. Below is a brief introduction of each of each of the eight participants who were chosen for this study.

Jennifer

Jennifer is the eldest in her family and has one younger sister. Her parents both worked, and she had a sheltered life. She was always interested in science and in chemistry. Her parents were born overseas, and her mother had given up an office job to work in the administration of the school in which she and her sister attended. Jennifer's father was involved in the building industry and often worked long hours and away from home.

Angela

Angela is the second child in her family. She has one older sister and one younger sister. Her father is American, and her mother is from the Philippines. Her mother works in a bank and her father was in the American Air Force. They met in the Philippines. Both her parents were born overseas, and had settled in Sydney, Australia

for the period the three daughters finished their schooling and university degrees. Her parents have since 2015 relocated to the Philippines. Angela now lives in Washington DC.

Anita

Anita is the third child in a family with nine children. Her father worked as an optometrist and her mother worked in the home looking after her many children. Anita was a very passionate science and mathematics student. In Year 10 she was involved with writing and acting in a science musical. Her science teachers enjoyed teaching her and were amazed by her general knowledge as well as her scientific and mathematical ability. Anita had many friends and was a good public speaker. She was chosen to take part in the TOSRA along with 16 other students.

Rita

Rita hails from a large family and her cultural background is Sri Lankan. Her father works for his own company and her mother is a housewife. She is the second child in a family with nine children. Rita has been a diligent student who has worked at her daily lessons with great consistency and was commended for this by her science and mathematics teachers in school. She had a strong work ethic and a sense of responsibility. Rita has always had a love for science and was an independent learner. She set high goals for herself in school and made up her mind to become a doctor even if she did not get a very high school qualifying mark. Her family ties were very strong, and her family members supported her in the academic choices she made in school and university. Rita did the TOSRA test after she had finished school.

Megan

Megan was born overseas in India and had studied in a Catholic school in western Sydney for early secondary school. She moved to a private girl's school for Years 11 and 12. She was a whole year younger than her classmates in this new school. Both her parents were teachers, originally from India. Her father was an ex-military man who had changed his profession after migrating to Australia. He now teaches advanced mathematics in an independent school in a north western suburb of Sydney. Megan's mother teachers business studies at the HSC level, and is also currently working in an independent school.

Charlotte

Charlotte is the participant who went to a different school from the other seven participants. She attended a selective state school and was encouraged by her parents to study science. Her background is Sri Lankan. Charlotte is from a small family with just on sibling, a brother. Charlotte joined the study while she was in university, replacing the original participant who left the study because she had changed her degree. Charlotte therefore did not answer the initial science attitude instrument TOSRA. The teachers who answered the Questionnaire TQ 3 had not taught her and so there is no information about her from teachers. However, Charlotte proved to be an ideal participant who was able to impart information about her early attitudes towards science, her school examination results, her academic journey through two science-related degrees and details of her family support throughout her studies. She did give this information later as compared to the other seven participants.

Nikolina

Nikolina is the second in a family of seven children. Her mother was a French teacher who hailed from New Caledonia and taught in the same private independent school her daughter attended. Nikolina's father was an architect. Nikolina is the eldest girl in the family and showed a deep interest in biology when she was in Year 10. She had natural ability in this subject was a lateral thinker and understandably she chose biology, for Year 12.

Xanthe

Xanthe hails from a small family, has three brothers and her parents work in jobs within the health field. Her father is a doctor. While she was growing up she was constantly fascinated with the stories about work which her parents related around the dining table. She was diligent hardworking and very interested in science from an early age. She was level headed and practical and a good organiser, so her classmates voted her as the class secretary in Year 12. Her teachers found that she had an aptitude for chemistry and biology and her Year 10 examination put her in the top 10% of the state of NSW. Xanthe was a cheerful friendly student in school and got on very well with her teachers.

Charlotte attended a different school, also for female students only, which was in a different suburb. Charlotte was not part of the original 16 participants and did not answer the early science attitude questionnaires.

TOSRA was the first science attitude detailed questionnaire given to the students with the intention of selecting suitable candidates for the study. In total there were 16 students initially selected and the average score on each item from the TOSRA questionnaire was compared with the students' individual score on each item (Table 4.5). Each item had ten questions and the maximum score for each question was 5 giving a total of 50 as shown in the table. Each participant's average for the seven items was also calculated. These scores are referred to in the discussion of each participant's early attitude to science.

Table 4.5 *Participant Scores on Science Attitude Questionnaire TOSRA (n=16)*

TOSRA item with ten questions	Participants								
	1	2	3	4	5	6	7	8	M
Total score	50	50	50	50	50	50	50	50	50
Social Implications of Science	39	40	40	40	44	n/a	38	44	37
Normality of Scientists	36	46	34	40	41	n/a	36	38	34
Attitude to Scientific Inquiry	39	32	37	33	30	n/a	28	34	36
Adoption of Scientific Attitudes	33	44	37	35	32	n/a	30	38	32
Enjoyment of Science Lessons	39	46	41	42	36	n/a	34	42	36
Leisure Interest in Science	36	43	41	41	27	n/a	25	39	35
Career Interest in Science	37	42	38	39	36	n/a	31	38	35
Mean for each participant	37	41.9	38.2	38.5	35.1	n/a	31.7	39	

Participants responses to the science attitudes instrument

Jennifer

Jennifer's positive attitude towards her studies and towards science was demonstrated clearly by the results of her TOSRA. This was the first questionnaire given to the students with the intention of selecting suitable candidates for the study. Results from the TOSRA questionnaire helped identify Jennifer's initial attitudes and interest in science. Her scores showed an enjoyment of science lessons (39/50), a positive attitude towards scientific inquiry (39/50) and an understanding of the social implications of science (39/50). Interest in a science career (37/50) a leisure interest in science (36/50) and the normality of scientists (36/50) also appear important to her at this stage (see Table 4.5).

Angela

Angela has been described by her science teachers in the school where she studied, as an all-round student whose love for science and science-related activities led her to choose physics as a subject for Years 11 and 12. She was interested in the history of science and the lives of scientists. This made her a likely candidate for this study and she was one of the initial 16 students chosen. It is evident from her TOSRA score of 46/50 on the item "Normality of Scientists", that she had a positive attitude towards science and scientists. Her responses show that she enjoyed her science lessons (46/50) and was able to understand, at an early age, the implications of science in the community (40/50). Her overall average for all the items on the questionnaire was 41.9/ 50 which was the highest score within the cohort. However, it must be mentioned that she sat the TOSRA, after she had finished school.

Anita

Anita's initial questionnaire results demonstrated an enjoyment of science lessons in school with a score of 41/50 and an understanding of the social implications of science for which she scored 40/50. She shows at this early stage a leisure interest in science which goes beyond the classroom lessons scoring 41/50 for this item.

Rita

Valid conclusions drawn from the TOSRA responses made by Rita after she finished school demonstrate an enjoyment of science lessons with a score of 41/50. Rita demonstrated a leisure interest in science scoring 41/50 for this item. She also demonstrated an awareness of the social implications of science and the normality of the scientists, scoring 40/50 for each of these items (see Table 4.5).

Megan

Megan presented in Year 11 as an average student with an interest in science. She demonstrated an understanding of the social implications of science from her initial discussions. Megan scored 44/50 on the social implications of science, and 41/50 on the normality of scientists showing a positive attitude towards science and science education. She enjoyed science lessons and was interested in a career related to science. Megan's responses point towards viewing scientists as normal people. While she has a career interest in science she does not see herself as a person who would spend her leisure time working on scientific activities.

Charlotte

Charlotte is the participant who attended a girls only selective state school, a different school from the other seven participants, but she had a similar education. Charlotte did not answer the initial science-related questionnaires of TOSRA but joined the study while she was in university, so data were obtained from her through questionnaires and her own recounts of her interests in science. Charlotte was diligent and did very well in her external examinations. While her family interest and involvement in her education was strong, so were her own characteristics of determination and dedication to education. She had a positive attitude towards education and towards science and mathematics from an early age.

Nikolina

Nikolina did not score very high in her TOSRA questionnaire though there is an evenness in her overall responses. Her average for all the seven items was 31.5/50. She viewed science and scientists as normal people and had a fair idea of the social implications of science scoring 38/50 for this item. She seemed to be enjoying her science lessons though her score of 34/50 was a little below the average of the cohort score which was 36/50 for this item. Since her responses were below average, she was

not initially chosen, but was later added to the study as she persevered while others who had been chosen dropped out of science courses.

Xanthe

Xanthe was diligent, hardworking and very interested in science from an early age. She was level headed and practical and a good organiser, so her classmates voted her as the class secretary in Year 12. Her teachers found that she had an aptitude for chemistry and biology and her Year 10 examination put her in the top 10% of the state of NSW. Xanthe was a cheerful, friendly student in school and got on very well with her teachers. She says that she knew while growing up that she did not want to go into a career which did not involve working with people in some way. Instead she wanted to work face-to-face with a range of people and personalities with the intention of 'helping them' become better to achieve a goal in some way. Xanthe has demonstrated a deep understanding of the social implications of science at school age scoring 44/50 for this item. Her overall interest in science outside the classroom was high demonstrated by a score of 39/50 and her enjoyment of science lessons is obvious from her score of 42/50 (see Table 4.5).

4.3 Research Question 1c: What are the sources of the students' interest in science in school?

School Science Environment

The school's science teachers worked closely with the careers' advisor to help students have a broad view of the career opportunities available to them which required some scientific background. The careers advisor frequently distributed pamphlets and notices about open days at universities, career-related talks at the University of Sydney and Macquarie University. There was an annual career's day held at Darling Harbour, in the city of Sydney, which served as an external excursion for all Year 10 and 11 students. Parents were also encouraged to attend to be better informed about the choice careers available at that time. The teachers of the science department met with each other on a regular basis to discuss all issues related to the teaching of science in the school.

In the year 2007, the students of Year 10 wrote a science musical called Helicobacter-Pylori which was performed on stage and which served as a great motivator to younger students enabling them to understand that science could be fun. (Two of the original 16 participants in this case study were involved in this play.) This play was about an Australian scientist, a gastroenterologist called Barry Marshall, who swallowed bacteria to prove that it could live in the human body and cause extreme gastritis which could lead to the formation of ulcers. He received the Nobel Prize for this discovery 20 years later (Marshall & Adams, 2008). While students of today realise that they may not use themselves as specimens for experiment, this true story, beautifully demonstrated through action and song served as a key motivator to create interest in science and scientific discoveries. The teaching staff in this science department encouraged the students to demonstrate their talents and encouraged the younger students to be involved in similar activities.

Scientific-treasure hunts were designed for younger students. Teachers hid scientific specimens from the laboratory in different areas of the school and students went on a hunt. In some situations, they had to complete a diagram or draw a specimen as part of the process. Further involvement and direction of the science faculty can be seen from the initiative they took in the years 2006-2010. During the period that the students were in senior school the science faculty organised an afternoon during science week activities called 'Women in Science' based on a similar program which had been held in Macquarie University. Some teachers had attended the Macquarie University presentation and were so motivated and encouraged by what they had seen and heard that they decided to adapt and run a similar event to encourage other students to want to study science.

The students were divided into groups and asked to meet with a science teacher in the faculty at school and interview the teacher. The students were to ask the teacher about the subjects she studied in school and about her decision to study science in university. As all the teachers were female and so were the students the discussion automatically would involve why science was considered so important although it was much harder than other traditionally female subjects. The students were then able to obtain photographs of graduations and early career years, to make the presentation more interesting.

‘Women in Science” was then presented to the whole secondary school. The students were captivated to see photos of their teachers when they were young. Many of the teachers of the faculty came from different countries such as South Africa, England and India, so their career journeys added a cultural attraction as well. One teacher had worked in the corporate world, another in research, and yet another had been a chemical engineer, before taking up science education. The students were captivated by the whole presentation and the generosity of the science teachers sharing their experiences and photos.

The teachers of the science department observed each other’s lessons as part of the school teacher assessment process. Regular meetings and sharing of ideas took place and younger staff were able to learn from the more experienced staff about methods which worked in the teaching and learning of science. In turn, younger teachers who were more able in using ICT successfully were able to help with the setting up and execution of ICT in the teaching of science concepts.

Teachers attended professional development courses regularly and on return to school carried out in-service activities within the department to share their knowledge and experiences. Sessions were held on the methods of writing multiple choice questions for science examinations after two members attended a two-day course at the University of New South Wales (UNSW) for an International Competition of Assessment (ICAS) Examination.

Teachers were also encouraged to become markers of the Higher School Certificate examination (which is used for university admissions) and to be involved with the examination committees. These sessions of marking the examination papers for the whole state were professional development courses by themselves and teachers learnt exactly how the system worked and were able to prepare their students better for the external examination. In addition to this there was a lot of exchanging of ideas and resources when teachers of both sexes and different levels of experience from all over the state met and worked together as a team. The confidence of teachers vastly improved after attending these marking sessions and therefore this had a positive impact on the teaching of science in the classroom and on the classroom climate.

Teaching Strategies

The teaching strategies employed by the science teachers in the school no doubt played a role in motivating the students to take up science as a subject in Years 11 and 12 and to consider a science or science-related degree and career. The teachers in the science department met once a fortnight to discuss issues related to the teaching and learning of science. One method used broadly in Years 7-10 was teacher demonstration of practical experiments. This was a method used especially if the apparatus was complicated (such as fractional distillation) or in short supply. Teacher demonstration would later allow for first hand investigations which were done individually or as a group with students in Years 11 and 12. These investigations were teacher guided both with the procedures as well as the write ups. Documenting the process using an iPad or camera also helped students to set up and display their results in a logical and interesting way. Staff members took students on science excursions to see 3D films, visit science museums and universities to motivate and further the methods of teaching science. In Year 10, classes were split so that different teachers could teach their subject matter depending on their expertise. One such example is that a teacher would teach one half of the class biology topics while another teacher taught the other half of the class physics. After topics were taught they would interchange classes. Students benefitted from more attention in smaller classes and from teacher expertise in the relative science subject. In this way, students were better prepared for the next year. Some details of the methods used by the science teachers are recorded under the subheadings below.

Teacher Demonstrations

Teachers taught a concept through practical demonstration of the apparatus or experiment. The use of laboratory apparatus to demonstrate a concept served to create immediate interest especially with younger students. With older students the observations could help further by triggering their imagination. During revision of the concept, the images of the demonstrated experiment would serve as stronger instruments for recall than diagrams from the student text book. Teacher demonstration using simulations from the internet and U-tube videos when used appropriately also served to reinforce and teach a concept. A variety of demonstration techniques is necessary to maintain student interest (Turner, 2015).

First Hand Investigations in the Laboratory

The New South Wales Standards Authority (NESA) syllabus requires varied investigations to be undertaken in physics, chemistry and biology in Years 11 and 12. So in keeping with this requirement students were able to carry out first hand investigations to arrive at specific conclusions. The process of carrying out the first-hand investigations required some teacher direction and the availability of the apparatus. Risk assessments were also carried out and teacher supervision was always necessary. The laboratory was usually the place for the conduction of the first-hand investigations, but sometimes other areas of the school had to be used (dropping balls from a high building or throwing a javelin and photographing its trajectory). Students would document their observations, readings or calculations using a format suggested by the textbook or teacher. These first-hand investigations were monitored closely by the teacher allowing the student to proceed after completing the risk assessment required for the experiment. Validity and reliability were key components of each experiment and were included in the write ups in the practical exercise books which were marked with a grade by the teachers regularly. Responses from the initial science-related attitude instrument TOSRA which was given to the students helped to determine areas of concern and the possibility of rectifying problems or reinforcing rules.

Documentation through Research using Photography

Some practical work involved experiments which could be documented using photography. For example, the crashing of plasticine dummies on dynamics trolleys to see the effects of seatbelts, when photographed or video recorded made the whole experiment more interesting and meaningful to the students. In the same way, static electricity effects from the Van de Graaf generator could be clearly demonstrated through the production of electric fields set up by grass seeds in oil and the static charging of a sphere producing strong visible electric sparks.

Group Work and Problem Solving

Students were grouped together randomly to put them out of their comfort zones. A problem which was scientific and related to the course was presented to each group and they were given time to solve this problem and present the solution to the class. Such a technique used in the classroom situation allowed the teacher to observe the

group dynamics and grade students according to their participation and contributions. Some students automatically took up the leadership role while others were able to contribute as their personality determined. This method of group work allowed for team building and team work which will better equip the students for university and the work force.

Presentation of Work from Secondary Investigation

Students who did research work using text-books, journals and the internet, subsequently, presented their work to the class in the form of power point or Prezi slides. This presentation gave the students an opportunity to enhance their confidence, with regular practice in public speaking and presentation.

Current Science Documentaries

The science faculty used current documentaries presented by famous people such as Sir David Attenborough and Professor Brian Cox to motivate and encourage the students to love science. The excellent digital photography, fluent commentary of these experts, and the attractive personality of the presenters served as a beacon of light to those students who may have thought that science was boring. The physics class was given the opportunity to watch movies such as Einstein's *Big Idea* (David Bodanis) which gave the history of Einstein's theory of relativity along with the history of the discovery of electromagnetism. Students were taken on excursions to the IMAX Theatre in Sydney's Darling Harbour to see 3D Films such as *Space Station* and *Magnificent Desolation: Walking on the Moon*, both contributing to the development of wonder and love for these great scientific achievements.

Specific Excursions

Classes in the school regularly attended science excursions. Years 7-10 each had an annual excursion whereas Years 11 and 12 had three specific excursions each for physics, chemistry and biology. One such excursion was to the Luna Park. Sydney which is a fun park with roller coasters, dodgem cars and various other rides. Worksheets related to forces, gravity and momentum were given to the students to complete after they had experienced the thrills of the rides. (https://www.lunaparksydney.com/school-groups). Similarly there were excursions to the Museum of Human Disease, in the University of New South Wales, Sydney, for biology (https://medicalsciences.med.unsw.edu.au/community/museum-human-

disease/home). Chemistry students went to the Nuclear Medicine and Forensic Laboratories at the Australian Nuclear Science and Technology Organisation (ANSTO). The students were able to study the process of creating nuclear isotopes in the ANSTO Lucas Heights Nuclear Reactor and learn about the application of these isotopes in agriculture, engineering and medicine. (http://www.ansto.gov.au/).

Kickstart Program in Physics and Biology at Sydney University

Year 12 physics and biology students attended annually the Sydney University Kickstart Program which was run by the departments of physics and biology. (http://sydney.edu.au/science/outreach/high-school/kickstart/index.shtml).

Undergraduate university students acted as demonstrators and students from schools from the country as well as the city and city suburbs attended. These special days devoted to the HSC coursework practical activities could be booked online and ran throughout the year. September was the ideal month to take part in this program as it helped the students consolidate what they had learned throughout the year. It also served as a good visual and hands-on preparation for any type of application question preparation for the final examination held in October. The students also spent a day at the university and met with senior students whose eloquence and interest in science only served to act as an example for them. Many questions were answered regarding the courses undertaken by the young university demonstrators. This program thus better prepared the students for their future in science.

Tutorial System

This school had a tutorial system which allowed every student in the school to have a non-academic tutor who would meet with the student every fortnight and discuss with them their overall progress both academic and general. The tutor would also meet with teachers and parents every term and pass on information about the student's progress and overall character development. While some schools have employed school councillors and psychologists to look after the mental health of their students who require additional support, this system was available for every student in the school. The tutor was able to guide and support the student in academic decisions such as subject choice for Years 11 and 12 and help to set career goals for the future. The tutor often worked closely the student for many years. Seven of the eight participants benefitted from this unique tutorial system.

4.4 Conclusion to Objective 1

This chapter has attempted to answer the three research questions related to the first objective, pertaining to the various aspects of the initial science attitudes held and gradually developed by the participants in their final years of school. The researcher considered that it was important to paint a picture of the school environment and the activities carried out by the teachers in the science department during that period. The positive influence of the school and the support of the home has helped to form a foundation upon which stronger attitudes may be built in the future.

The scores in Figure 4.1 have been obtained from the TOSRA questionnaire given to seven of the eight participants when they were in school or early university years. The results show the early attitude scores on specific items (see Table 4.5).

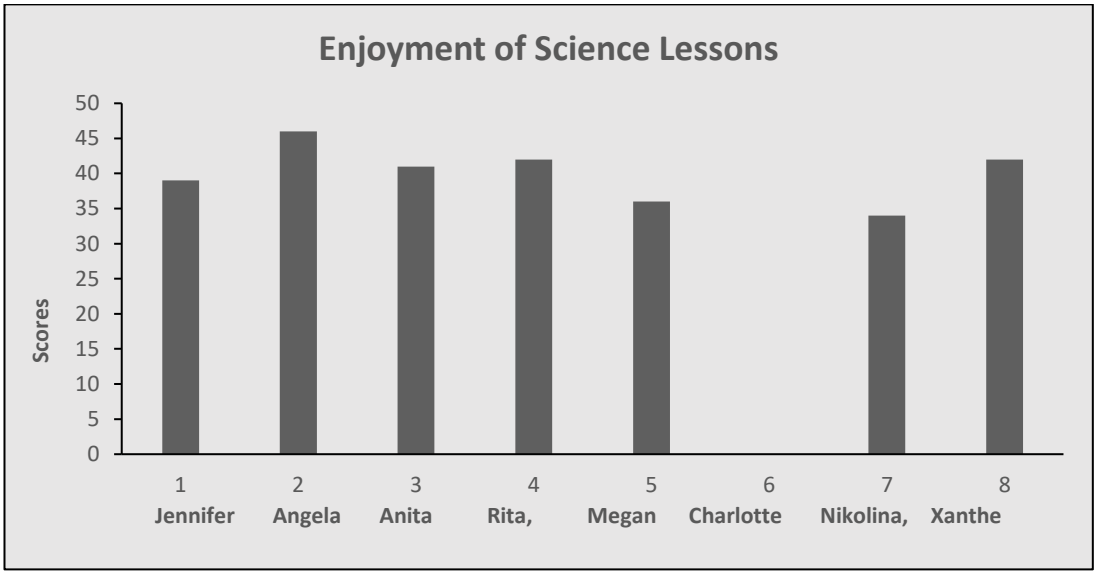


Figure 4.1 *TOSRA Scores: Enjoyment of Science Lessons.*

There is a common thread of similarity showing indeed that the participants had a positive attitude and enjoyed their science lessons in school. Further comparison of their early attitudes towards scientific inquiry is shown in Figure 4.2.

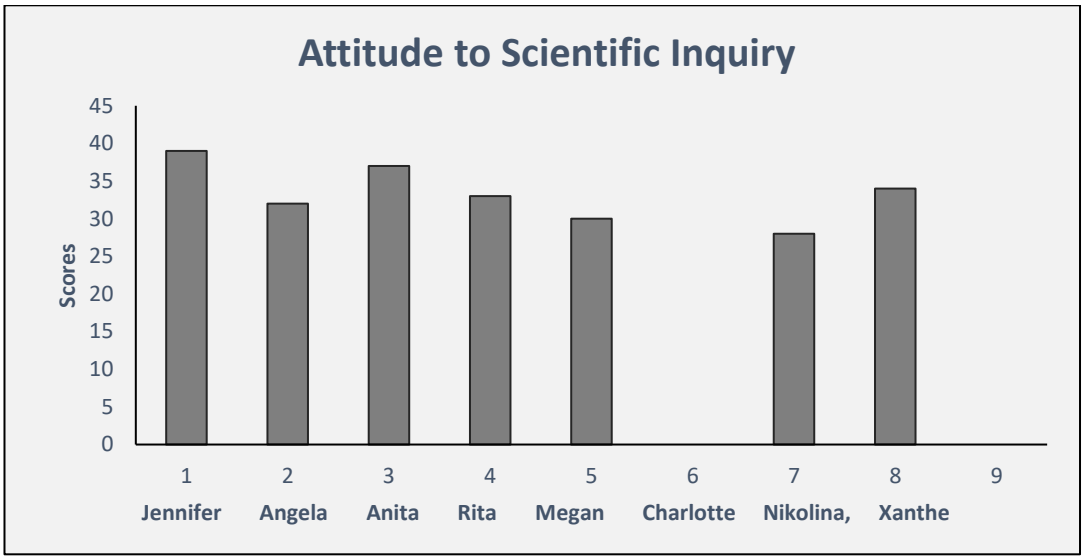


Figure 4.2 *TOSRA Scores: Scientific Inquiry.*

Figure 4.3 connects the student"s attitudes with the source of these attitudes in their school. Teaching strategies and the school environment have played a role in developing these attitudes. The TOSRA specific item scores link well with the sources within the school as shown below

Participant	TOSRA Item: (Table 4.5)		Source of interest in school
	Enjoyment of Science Lessons	*Attitude to Scientific Inquiry*	
Jennifer	39 Strong	39 Strong	School science environment
Angela	46 Strong	32 Medium	
Anita	41 Strong	37 Strong	Teaching strategies
Rita	42 Strong	33 Medium	Teacher demonstrations
Megan	36 Strong	30 Medium	
Charlotte	n/a n/a	n/a n/a	First hand investigations in the laboratory
Nikolina	34 Medium	28 Medium	
Xanthe	42 Strong	34 Medium	Second- hand investigations based on research

Figure 4.3 *Enjoyment of Science Lessons and Attitude to Scientific Inquiry link with school science environment*

The strong and medium scores demonstrate the fact that the students enjoyed their science lessons in school and had developed the skills of scientific inquiry. It can be

concluded that the school environment and the teacher led learning experiences have no doubt contributed towards this positive attitude.

Similarly Figures 4.4 and 4.5 demonstrate the students' understanding of the social inplications of science and identify their career interests in science. These attitudes are linked with the school's teaching strategies and the learning environment in which the participants spent most of their school lives

Participant	TOSRA Item: *Social Implications of Science* Score on 50 and score description	Source of interest in school
Jennifer	39 Strong	Science documentaries made by famous scientists and TV presenters. Using photography for documenting work Presentations in class, science plays for the school assemblies and science excursions. Visits to the university for specific experiments. Science week activities
Angela	40 Strong	
Anita	40 Strong	
Rita	40 Strong	
Megan	44 Strong	
Charlotte	n/a n/a	
Nikolina	38 Strong	
Xanthe	44 Strong	

Figure 4.4 *Social Implications of Science link with school science activities*

The strong scores demonstrate the fact that the students had very good exposure to science outside the text book. The acting out of a science play for the rest of the school has allowed them to understand the social implications of a scientific discovery, the visits to the university and excursions allow for science to be applied to every day activites as do presentations made in the classroom. Documnetaries by television presenters such as David Attenborough and Brian Cox on climate change and the destruction of the world reefs has enhanced their understanding of the social implications of science.

Participant	TOSRA Item: *Career Interest in Science* Score on 50 and score description		Source of interest in school
Jennifer	37	Strong	School presentations such as "Women in Science" (p. 65) Science Teacher role models Science Day activities and Career day excursions
Angela	42	Strong	
Anita	38	Strong	
Rita	39	Strong	
Megan	36	Strong	
Charlotte	n/a	n/a	
Nikolina	31	Medium	
Xanthe	38	Strong	

Figure 4.5 *Career Interest in Science link with specific science presentations*

These scores show that the sharing of the career paths of the science teachers within the school, the activities experienced at school-related career talks, and the guided external excursions have led to the students developing a career interest in science.

It can be concluded, based on the evidence from answers to early questions from the research, that the eight participants were really interested in studying science. Responses and subsequent scores on specific items from TOSRA demonstrated the fact that all eight participants had a positive attitude towards science and science education. This positive attitude which stemmed from the school science teaching strategies and the school environment has directed them towards the choice of a science degree in university.

CHAPTER 5

ACADEMIC JOURNEYS

"Character cannot be developed in ease and quiet. Only through experience of trial and suffering can the soul be strengthened, ambition inspired, and success achieved" - Helen Keller (Manser, 2001, p. 32).

5.0 Overview

This chapter is related to the second objective which aimed to investigate the correlation between school examination results and the choice of subjects for a University degree. The study has investigated the link between the results of the students in the Year 10 School Certificate examination, Year 12 Higher School Certificate examination, and the successful completion of the undergraduate degree in science or science-related subjects. The research has investigated the personal characteristics of each individual which have been responsible for their success in persevering and completing their science degree.

The second objective has been classified under three research questions.

2a: Does the student's performance in the School Certificate and Higher School Certificate examinations correlate with her subject choice for a degree?

2b: Which undergraduate and post graduate degrees did the participants complete successfully?

2c: What role did the student's personal characteristics play in helping her to conclude the degree she had started, and in some cases go on to study for post graduate degrees?

In this chapter, the academic journey of each participant from school to university and beyond is discussed with relevance to examination performance, degree completion and personal characteristics responsible for perseverance and success.

5.1 Research Question 2a: Does the student's performance in the School Certificate and Higher School Certificate examinations correlate with her subject choice for a degree?

During the period of this study and when data were initially collected, the students of NSW sat for an external examination at the end of Year 10. This examination served as a standard for the whole state. Students could leave school after sitting for this examination and take up a TAFE course, a trade apprenticeship or move interstate. It was assumed that only about 50% of the students in the state would then go on to do the Higher School Certificate which also served as the entrance examination to all the universities. Therefore, those students who commenced the HSC did so with the intention of completing a University degree. After 2012, the Year 10 School Certificate Examination was terminated, and students are now expected to continue with their education to Year 12. Many schools set their own end of Year 10 examination. The School Certificate and Higher School Certificate were the external examinations which students in NSW had to complete successfully to be admitted into a university course. Results of the science examination for the School Certificate have been collected and compared to the results of the Higher School Certificate. There seems to be a positive correlation between the two, showing that a student who scored a Band 6 (above 90%) in Year 10 would likely score a Band 5 or 6 in the HSC, for whichever specific science subject the student had taken. Physics and chemistry were considered harder than biology (at that time and with that course) and the cohort who sat for these subjects were likely to score a Band 5 (80- 89%) as a minimum. The eight participants all sat for the same external school examination, and these details are discussed in the following pages. General information was obtained from Questionnaire PAU 1 (Table 3.4) and notes were written and refined (see sample memos in Appendix D).

Jennifer

Jennifer attended a private independent school for girls. She was taught by female teachers. Her mother also worked in the same school though she was not a teacher but an administrator. Jennifer made friends easily and has happy memories of school, her teachers and her friends. (Questionnaire PAU 1 Table 3.4).

During her school term Jennifer had participated in the Science International Competition and Assessment for schools (ICAS) competitions from Years 7-11. This competition is conducted annually in Australia and in over 20 countries in Asia, the Pacific countries and in America. It is an independent skill–based assessment program used by Education Assessment Australia. Teachers in New South Wales use the results of this competition as an assessment to identify students' abilities and strengths, especially in science, English and mathematics. Jennifer excelled in this competition and has obtained credits and distinctions throughout her secondary school years.

Jennifer obtained a Band 6 (90% or more) for her School Certificate examination in 2004. This corresponded with a very high Band 5 (89%) in chemistry for the Higher Secondary examination in 2006. Her results in both external examinations placed her in the top 10% of students in the state of NSW. Figure 5.1 shows her school results and the degree she chose to complete in university.

School Certificate result in Science	Band 6 (90-100)
Higher School Certificate result in Chemistry	Band 5 (80-89)
University Course	Bachelor of Biotechnology
Science subjects linked to school subjects	Chemistry and Biology

Figure 5.1 *Jennifer's School Results and University Course.*

Angela

Angela had always worked hard and in the Year 10 examination received a Band 5 for Science (80-90 %). She took up physics as her science subject for Year 12 and obtained a high Band 5 for the Higher School Certificate scoring 87% which put her in the top 10% of the state of NSW for the year 2007. This result encouraged her to apply and be accepted into Macquarie University. Angela had started initially with a degree in engineering but after completing the year, she withdrew realising that this was not the course to pursue. She had to take one semester off because she had missed the enrolment date. This was a very trying time and left her confused about her academic abilities and stressed about having to pursue a new course. She was feeling less confident for 'dropping out". She felt that the support of her parents and siblings (one older sister and one younger sister) helped her to start again and plan her next

steps to go back to university. Figure 5.2 shows her school results and university course.

School Certificate result in Science	Band 5 (80-89)
Higher School Certificate result in Physics	Band 5 (80-89)
University Course (initial) University Course (final)	Engineering Bachelor of Environmental Science
Science subjects linked to school subjects	Physics, Environmental Science, Biology

Figure 5.2 *Angela's School Results and University Course.*

Anita

Anita has been a school house captain and has shown leadership qualities. Her performance in school has been exceptional in chemistry and mathematics. She has been a diligent student and has also taken part in debating and sport. She was an exceptionally good debater and represented the school in the Independent Schools Debating competition. Anita was an intelligent student who was highly motivated to study both mathematics and science. She consistently obtained credits and distinctions in science and mathematics in the International Competition and Assessment for Schools (ICAS) in Years 7-11. In her Year 10 School Certificate examination, she scored a Band 6 in science (> 90%). She took up advanced mathematics, physics and chemistry for Year 12 (see Table 4.1) and did very well in the Higher School Certificate examination obtaining a Band 6 for chemistry (>90%) and a high Band 5 for physics (>85%). These excellent marks in the external examinations confirmed the fact that Anita was a very good science student and that science would play a role in her choice of university course. Anita had excelled in mathematics as well scoring over 95% for the Higher School Certificate examination.

She sat for the Undergraduate Medical and Health Science Admission Test (UMAT) in July 2009 and obtained 80%. She then decided against doing medicine (see Questionnaire PAU 1 Table 3.4). Anita obtained a place in the University of New South Wales to enrol in a four-year degree in Science/Optometry. Figure 5.3 displays Anita's school results and university course.

School Certificate result in Science	Band 6 (90-100)
Higher School Certificate result in Physics Higher School Certificate result in Chemistry	Band 5 (80-89) Band 6 (90-100)
University Course	Bachelor of Science/ Optometry
Science subjects linked to school subjects	Physics, Chemistry

Figure 5.3 *Anita's School Results and University Course.*

Rita

Rita could be referred to as a high achieving student. In 2006, she sat the School Certificate examination and obtained a Band 6 ((90%) in science. She chose chemistry and advanced mathematics for her Year 12 subjects and scored a Band 6 in each for the Higher School Certificate examination in 2008. In chemistry she obtained 91% and in mathematics 94%. Her Australian Tertiary Admission Rank (ATAR) which is the number which determines a student's entry into university, was 96.4 putting her in the top 3.6 % of the state of NSW. With these incredibly good results one would expect that Rita could gain direct admission into any degree she chose to take up. Rita was admitted to the Bachelor of Medical Science at Sydney University in 2009. Even though she wanted to become a medical doctor and had obtained a high ATAR, she did not make the cut off mark for the undergraduate medical degree at Sydney University. She took up the Bachelor of Medical Science degree with the intention of using it as a stepping stone to a medical degree. At the end of the year she had successfully obtained admission to a Bachelor of Medicine at the University of Western Sydney, thus achieving the beginning of her dream. Figure 5.4 shows Rita's school results and university course.

School Certificate result in Science	Band 6 (90-100)
Higher School Certificate result in Chemistry	Band 6 (90-100)
University Course (initial). University Course (final)	Bachelor of Medical Science Bachelor of Medicine
Science subjects linked to school subjects	Physics, Chemistry

Figure 5.4 *Rita's School Results and University Course*.

Megan

Megan was one year younger than her classmates, but this did not deter her progress through school or university. In the Higher School Certificate, she scored a Band 5 in biology and she successfully completed her Bachelor of Science from Western Sydney University, as shown in Figure 5.5. This undergraduate degree was a stepping-stone in the direction of achieving her dream. (An ATAR for becoming a vet is >96% in most universities.) Megan found that the mode of delivery in university was quite different to school and so grasping major concepts particularly in chemistry and biochemistry was slightly difficult. She attended weekly tutorials and group study sessions. She also attended organised study sessions with friends to go through concepts most students found difficult. One-on-one meetings with lecturers also helped (see Questionnaire PAU 1 Table 3.4). Figure 5.5 shows Megan's school results and university course.

School Certificate result in Science	Band 5 (80-89)
Higher School Certificate result in Biology	Band 5 (80-89)
University Course	Bachelor of Animal Science
Science subjects linked to school subjects	Biology Chemistry

Figure 5.5 *Megan's School Results and University Course.*

Charlotte

Charlotte's results in the School Certificate Examination at the end of Year 10 were extremely good all round. She obtained a Band 6 scoring more than 90% in science. She chose both physics and chemistry for her HSC subjects and obtained a Band 6 in chemistry, scoring over 90% and a Band 5 in physics scoring over 80%. She started in Sydney University with a Bachelor in Science (Advanced) which she later adjusted to a Bachelor of Science with Honours in Psychology, as her undergraduate degree. She changed because she found the physics and chemistry units of study challenging and did not have the confidence to continue with them. She had developed a passion for psychology and decided to take this up as her honours subject. She successfully completed this degree and enjoyed the whole academic journey, making friends with

other students who had the same passion for psychology. Figure 5.6 shows Charlotte's school results and university course.

School Certificate result in Science	Band 6 (90-100)
Higher School Certificate result in Chemistry Higher School Certificate result in Physics	Band 6 (90-100) Band 5 (80-89)
University Course	Bachelor of Science/ Psychology
Science subjects linked to school subjects	Physics, Chemistry

Figure 5.6 *Charlotte's School Results and University Course.*

Nikolina

Nikolina had showed promise with her Year 10 science results producing a Band 6 with a mark higher than 90% putting her in the top 10% of the state of NSW. For the Higher School Certificate, she scored a Band 6 (>90%) in biology and a Band 5 (>80%) in mathematics. Nikolina could be considered a late developer as her success in the HSC exceeded all her previous examinations and set her up for a promising career. She was accepted into a Bachelor of Science at Sydney University in 2008. Figure 5.7 shows Nikolina's school results and university course.

School Certificate result in Science	Band 6 (90-100)
Higher School Certificate result in Biology	Band 6 (90-100)
University Course	Bachelor of Science
Science subjects linked to school subjects	Biology.

Figure 5.7 *Nikolina's School Results and University Course.*

Xanthe

Xanthe's positive attitude towards science education steered her to choose biology and chemistry as her Year 12 science subjects. She had performed extremely well in the School Certificate examination in Year 10 achieving a Band 6 in science (>90%). She was very involved in her studies and interested in first hand investigations performed in the laboratory. She obtained a very high Band 5 in chemistry (89%) and a Band 6

in biology (94 %). She received an ATAR of 95.75% placing her in the top 4% of the state of NSW. She had also consistently obtained distinctions in ICAS Science Competitions during her school years. Figure 5.8 shows Xanthe's school results and chosen university course.

School Certificate result in Science	Band 6 (90-100)
Higher School Certificate result in Biology Higher School Certificate result in Chemistry	Band 6 (90-100) Band 5 (80-89)
University Course	Bachelor of Applied Science
Science subjects linked to school subjects	Biology

Figure 5.8 *Xanthe's School Results and University Course.*

5.2 Research Question 2b: Which undergraduate and post graduate degrees did the participants complete successfully?

Jennifer

Jennifer was able to enrol in Macquarie University successfully due to her good HSC results. She had to learn how to adapt to university life and to travel on her own by train. Her parents encouraged her to be independent. Jennifer obtained three distinctions (Introductory Chemistry, Biochemistry and Molecular Biology 1, and Human Biology) and 14 credits in her degree.

She decided to complete her masters degree in Biotechnology in 2010/ 2011 because she felt that this course would lead to improving her job prospects. She was interested in working in the pharmaceutical field. The units of study Jennifer undertook to complete a Bachelor of Biotechnology from 2007-2009 are shown in Figure 5.9.

Year 2007	Evolution and Biodiversity, Thread of Life, Introductory Chemistry A, Introductory Chemistry B, Advanced Chemistry A, Advanced Chemistry B, History and Philosophy of Molecular Science, Introductory Histology, Mathematics 1A, Physics 1A
Year 2008	Animal Structure and Function, Organic Synthesis, Physical Chemistry, Chemical Analysis 1, Microbiology, Biochemistry and Molecular Biology 1, Biochemistry and Molecular Biology 11.
Year 2009	Human Biology, Molecular Biotechnology, Technology Mini- Project, Protein Discovery and Analysis, Medicinal Chemistry, Molecular Biology, Cell and Developmental Biology

Figure 5.9 *University Course completed by Jennifer with units of study.*

Angela

Angela had always been interested in environmental and social development issues from the time she started studying science and geography in school. She had made regular trips to the Philippines during primary and secondary school with her parents. After seeing first-hand the effects of environmental degradation on the environment due to the tsunami in the Philippines, it become clear to her that studying environmental management was a practical way of blending her passion for social justice and environmental studies. She then enrolled in and completed a Bachelor of Environmental Science degree at Macquarie University, Sydney NSW in 2010, three years after completing school. She received nine distinctions and seven credits for her first degree and this motivated her to continue to study in and enrol in a Master of Science in Environmental Health before taking up a full-time job working in environmental health. Figure 5.10 shows the units of study Angela completed for her degree.

Year 2010	Human Biology, Foundations of Resource and Environmental Management, Biophysical Environments, Geographies of Global Change, The Planet Earth, Language Culture and Communication.
Year 2011	Environment and Sustainability, Geographic Information Systems, Resource and Environmental Management Issues and Solutions, Earth Surfaces Processes, Environmental Analysis using GIS, Economy and Society.
Year 2012	Environmental Decision Making, Environmental Management Project, Environmental Management, Geographical Perspectives on Population, Asia Pacific Development, Resource Management, Geographies of Health, GIS for Urban and Regional Management, IT and Society.

Figure 5.10 *University Course completed by Angela with units of study.*

Anita

Anita's academic performance in University was very successful. Overall, she achieved nine high distinctions, 17 distinctions and six credits for her Bachelor of Science/ Optometry from the University of New South Wales. Because of her outstanding performance she was awarded two prizes. In 2013, she was awarded the Luxottica Prize for Ocular Therapeutics in Year 4 for the highest average result in OPTM4151 Ocular Therapeutics 4A and OPTM4251 Ocular Therapeutics 4B. In 2014, she received the UVEX Safety Australia Pty Ltd Prize for the best performance in the Bachelor of Optometry, Bachelor of Science in Environmental Optometry. Figure 5.11 gives the details of her units of study.

Year 2010	Molecules, Cells and Genes, Higher Chemistry, Mathematics, Physics, Biological Chemistry for Optometry, Psychology, Vision Science, Optics
Year 2011	Optometry2A, Physiology, Physiology of the Ocular System, Optics and the Eye, Optometry 2B, Physiology, Functions of the Visual System, Introduction to Ocular Disease.
Year 2012	Optometry 3A, Ocular Disease 3A, Aging and the Visual System, Medicine 4A, Optometry 3B, Ocular Disease 3B Pharmacology for Optometry 3B, New Development in Vision Science.
Year 2013	Optometry 4A, Clinical Optometry 4A, Ocular Therapeutic Optometry, Psych and Stats for Optometry, Optometry 4B Clinical Optometry 4B, Ocular Therapeutics 4B, Professional Optometry.
Year 2014	Clinical Optometry 5A and 5B Specialist Clinical Optometry 5A and 5B Clinical Ocular Therapeutics 5Aand 5B Research Project 5A and 5B

Figure 5.11 *University Course completed by Anita with units of study.*

Rita

Rita initially started studying for a Bachelor of Medical Science at Sydney University in 2009. Figure 5.12 represents her first year of University study.

Year 2009	Chemistry 1A Life Science, Concepts in Biology (Advanced), Physics 1 (Fundamentals), Biostatics, Life-Science Calculus, Molecular Biology and Genetics (Advanced), Introduction to Linear Algebra, Chemistry 1B Life Sciences, Physics 1(Environment Life Science), Differential and Difference Calculus

Figure 5.12 *Initial Course taken up by Rita in 2009.*

Rita did very well in her first year obtaining three distinctions and six credits in the nine units of study for the year 2009. In the same year Rita sat for the UMAT (Undergraduate Medical and Health Sciences Admission Test) which is a three-hour test used to select students into high demand careers such as medicine and dentistry. At the end of the year she had successfully obtained admission to a Bachelor of Medicine at the University of Western Sydney. Rita successfully completed her medical degree as shown in Figure 5.13 obtaining seven credits and three distinctions.

Year 2010	Foundations of Medicine 1, Foundations of Medicine 2
Year 2011	Foundations of Medicine 2
Year 2012	Integrated Clinical Rotations 1
Year 2013	Integrated Clinical Rotations 2
Year 2014	Integrated Clinical Rotations 3

Figure 5.13 *Final University Course completed by Rita with units of study.*

Megan

Megan completed a Bachelor of Animal Science during the years 2009-2012 from the University of Western Sydney. She worked hard and found some units of chemistry in the course difficult but refused to be discouraged. Instead she sought the help of friends in her class and with family support did consistently well in all the units of study she undertook. She preferred not to disclose her unit grades but her general feedback was that she had successfully completed all the units for the course (see Figure 5.14).

Year 2009	Biology 1, Chemistry 1, Introduction to Animal Science Human Animal Interactions, Biology 2, Chemistry 2, Practicum Animal Science.
Year 2010	Biochemistry, Microbiology, Animal Nutrition and Feeding, Animal Health and Welfare, Food Production Development, Genetics, Food Processing and Analysis
Year 2011	Applied Nutrition, Animal Production Animal Behaviour, Conservation Biology Food Quality Assurance, Introduction to Information Technology, Vertebrate Biodiversity.
Year 2012	Animal Reproduction, Laboratory Quality Management Analytical Microbiology, Ecology, Aquatic Ecology

Figure 5.14 *University Course completed by Megan with units of study.*

Megan had always performed well in her practical classes in school. She found the university practical classes and fieldwork units helped her to improve her skills and consequently her grades. Megan had the advantage of living at home while she studied in university and as she lived relatively close to the university she had plenty of time to focus on her studies and assignments.

Charlotte

Charlotte completed a Bachelor of Science with Honours in Psychology from Sydney University. She obtained a first class for her first degree with four high distinctions, six distinctions, and five credits. Figures 5.15 and 5.16 represent the units of study corresponding to the two degrees she completed successfully.

Year 2007	Chemistry 1A (Advanced), Education, Teachers and Teaching, Differential Calculus, Linear Algebra, Physics 1A (Advanced), Chemistry 1B (Advanced), Integral Calculus and Modelling, Statistics (Advanced), Physics1B(Advanced), Psychology 1002.
Year 2008	Molecular Reactivity & Spectroscopy (Advanced), The Birth of Modern Science, Linear Mathematics & Vector Calculus (Advanced), Probability and Statistical Models (Advanced) Chemical Structure and Stability (Advanced), Partial Differential Equations Intro Advanced, Optimisation & Financial Mathematics Advanced, Statistical Tests (Advanced).
Year 2009	Psychology 1001, Brain and Behaviour, Statistics & Research Methods for Psychology, Cognitive and Social Psychology, Personality and Differential Psychology, Advanced Statistics for Psychology
Year 2010	Learning and Behaviour, Abnormal Psychology, Behavioural and Cognitive Neuroscience, Developmental Psychology

Figure 5.15 *University Course completed by Charlotte with units of study.*

Charlotte then went on to complete a postgraduate degree in clinical neuropsychology from Macquarie University. Following her first degree in psychology, she was deeply interested in the human brain function and how the mind worked. Charlotte is now married and studying to become a medical doctor in Notre Dame University, Fremantle Perth.

Year 2013	Neuro-psychopathology, Neuropsychology Disorders, Psychological Assessment II, Psychological Assessment I, Neuroanatomy for Neuropsychologists
Year 2014	Developmental Neuropsychology, Cognitive Neuropsychology, Neuro psychopharmacology, Behavioural Management and Psychopathology, Neuropsychological Rehabilitation and Intervention, Supervised Practical Placement I, Supervised Practical Placement II, Professional Practice I, Professional Practice II
Year 2015	Research Design and Evaluation, Supervised Practical Placement III, Supervised Practical Placement IV, Professional Practice 3, Professional Practice 4.

Figure 5.16 *Second Degree completed by Charlotte with units of study.*

Nikolina

Nikolina was accepted into Sydney University to a Bachelor of Science degree which she completed during the years 2008-2011. She had been a keen biology student when she was in school and was eager to continue to study this subject in university. She enlisted in many biology units of study which are recorded in Figure 5.17.

Year 2008	Life Sciences Calculus, Biostatistics, Psychology 1001, Sociology, Living Systems (Biology), Chemistry 1A Introductory Geography, Differential and Difference Equations, Introduction to Linear Algebra
Year 2009	Conservation Biology and Applied Ecology, Natural Hazards: A GIS Approach, Oceans, Coasts and Climate Change, Introduction to Marine Biology, Environmental and Resource Management, Urban Geography Aquaculture
Year 2010	Tropical Wildlife Biology and Management, Animal Physiology, Marine Biology, Coastal Environments and Processes, Coral Reef Biology, Environmental Assessment, Energy and the Environment.
Year 2011	Environmental Law and Ethics, Regional Development and Environment

Figure 5.17 *University Course completed by Nikolina with units of study.*

Nikolina was interested in marine environments coral reefs and the laws connected with the environment. Her interest was in practical science, field trips, excursions and laboratory experiments. Nikolina's focus on climate change and its consequences motivated her to look for units of study which would give her a deeper understanding of these processes. While she found the mathematics and chemistry units in university quite challenging, she did well in the units of study linked to geography and biology.

Nikolona's interest in environmental science units led her to be involved in council and community meetings as well as debates and conferences which brought together people concerned with the problems facing the future generations. She was an active campaigner in demanding for the next generation, a better quality of life and a better understanding of the natural environment.

Xanthe

Xanthe had chosen her course after long consideration and research to be sure that it was what she wanted. Xanthe was confident that she wanted to work in health when she started, hence her motivation to complete the course was high. When looking at university courses she knew that she did not want to enter a long course, nothing more than five years, because she was eager to get out into the workforce. It was therefore a combination of these factors which led her to investigate the courses of nursing, physiotherapy and occupational therapy (OT). Ultimately, she chose occupational therapy as it held a combination of biology, anatomy, psychology, creativity and was centred on helping others achieve their goals. (Questionnaire PAU 1, Table 3.4). She decided to enrol in a Bachelor of Applied Science (Occupational Therapy) from the university of New South Wales during the years 2011-2014. Figure 5.18 gives details of the units of study which make up her degree.

Year 2011	Human Cell Biology, Health Behaviour and Society 1, Understanding Occupation People –Contexts Family, OCC Performance-Self Care and Mobility, Functional Musculoskeletal Anatomy A, Teaching Occupational and Performance: Community, Occupational Performance: Healthcare 1 and Family, Professional Practice 1.
Year 2012	Health Science and Research, Occupational Performance Healthcare, Occupational Performance Home, Professional Practice 2, Neuroscience, Occupational Performance: Community, Occupational Performance: Child, Public Offenders: Criminality and Rehabilitation
Year 2013	Professional Practice 111A, Professional Practice 111B, Disease in Ageing, Occupational Performance Education, Occupational Performance Productivity, Occupational Performance Retirement
Year 2014	Upper Limb and Hand Rehabilitation, Occupational Therapy in Work Injury, Prevention and Rehabilitation, Professional Elective General, Health Promotion through Occupation, Evaluation in Professional Practice, Professional Practice IV

Figure 5.18 *University Course completed by Xanthe with units of study.*

5.3 Research Question 2c: What role did the student's personal characteristics play in helping her to conclude the degree she had started, and in some cases go on to study for post graduate degrees?

Information other than examination results was obtained from two early questionnaires PAU 1 and PAU 2. General information obtained from PAU 1 has been referred to in the responses to the first part of the second research question. The third part of the second research question uses information obtained from PAU 2, seeking

to identify the role played by the participants personal characteristics. (see Table 3.4 and Appendix E). The responses of the eight participants have been recorded in Table 5.1 indicating scores of participants for each scale item from the questionnaire. The questionnaire was made up of seven items each containing three questions. The maximum score for each question was five, thus allowing a total score of 15 for each item.

Table 5.1 *Participant Scores for Questionnaire PAU 2 (n=8) (see Appendix E)*

	Participants								
Scale Item	1 J	2 A	3 A	4 R	5 M	6 C	7 N	8 X	M
Total Score	15	15	15	15	15	15	15	15	15.0
Personal Traits	15	15	14	15	13	14	13	13	14.0
Friends	13	13	12	14	12	13	12	11	12.5
Family Influence	12	12	11	13	11	12	11	9	11.4
Teacher /Mentor Influence	11	11	10	12	10	11	10	10	10.6
Career Influence	11	10	9	11	9	10	9	10	9.9
Scientists	10	10	8	9	8	9	8	10	9.0
Government	9	9	8	8	7	8	8	8	8.1

Table 5.2 *Reliability of Questionnaire PAU 2 (n=8) (see Appendix E)*

Scale Item	No of items	Example Item	Cronbach alpha Reliability
Personal Traits	3	I worked very hard and gave up free time to work in the library focusing on assignments and examinations.	.83
Friends	3	I had friends in university who encouraged and helped me to persevere even when it was difficult	.98
Family	3	I have had discussions with my parents about my choice of Science subjects for the HSC.	.83
Teachers/ Mentors	3	I have been influenced by my teachers and career advisors to take up a Science/ Science related degree.	.85
Career	3	I was influenced by the social environment during the period of my study years to take up and complete the course.	.74
Scientists	3	I often read about scientists and recent science innovations in science magazines and journals.	.72
Government	3	I feel that there is a direct link between the jobs available for science graduates and the government support for science in schools and universities	.72

Table 5.1 records the participant scores for Questionnaire PAU 2 and identifies Personal Traits with a mean score of 14 as the most compelling factor. Mean scores show friends are the next strongest influence followed by family and teachers. Scientists and the Government play a smaller influential role. These external influences on the participants shall be discussed in Chapter 6.

As personal traits were identified as the strongest influence on the participants' success, the questions and individual scores for each question from PAU 2 are reproduced in Figure 5.19. (See Appendix E for questions and scoring method.)

Scale Item: Personal Traits
Q 15. My character and personal traits played a role in helping me to complete my degree.
Q 16. I worked very hard and gave up free time to work in the library focusing on assignments and examinations.
Q 17. I felt that I had the ability to complete the degree successfully because I had a positive attitude towards science education, one I had developed in school.

Question	Jennifer	Angela	Anita	Rita	Megan	Charlotte	Nikolina	Xanthe
15	5	5	5	5	5	4	5	5
16	5	5	4	5	4	5	4	3
17	5	5	5	5	4	5	4	4
Total	15	15	14	15	13	14	13	13

Mean = 14 n = 8

Figure 5.19 *Questions and Scores for Scale Item Personal Traits (PAU 2, see Appendix E).*

5.4 Participant summaries based on responses to Questionnaire PAU 1 and the Scale Item Personal Traits of PAU 2

Jennifer

When she was enrolled in university courses, Jennifer's interests went beyond science. She was the secretary for Macquarie Dance Company (MDA). She competed in dance competitions and was also heavily involved in running the society, organising weekly dance classes and competitions. Jennifer had to support herself and she worked 20-25 hours a week as a barista with Gloria Jeans which is a very popular franchised coffee and cake cafe. Her main work times were Friday through to Sunday. She was also a private tutor for Years 11/ 12 for English mathematics and chemistry working 4-8 hours a week.

Jennifer was asked to give further information through Questionnaire PAU 1 (see Table 3.4) about various aspects of her student life which included travel and work. She did travel to the USA and South East Asia thus allowing herself some time away from study. She also answered questions which asked her to identify factors which helped her to persevere and to focus on her studies and the tasks required by the rigorous course she had chosen. She felt that her character helped her to persevere as she considered herself to diligent and organised and could be calm at most times. Jennifer said that she felt she had managed her time between studies, dance, work and travel extremely well.

Jennifer enjoyed her first degree and decided to complete her Masters' Degree in Biotechnology in 2010-2011 because she felt that this course would lead to improving her job prospects. She was interested in working in the pharmaceutical field.

Jennifer began work as a sales consultant for Phenomenex, Australia in 2011. Phenomenex is a company which was founded in 1982 initially distributing chromatography columns which they later manufactured. The company tests chemical compounds. In 2012 Phenomenex developed a test for carbendazim[2] to prevent a recent rise in the fungicide's presence within the American orange juice supply. The company has also developed a new method for the detection of alcohol consumption that can detect consumption up to 80 hours after the body's exposure to it.

Jennifer's units for study in her bachelor's degree served as a firm foundation for the work she took up in this company as she now had an in-depth knowledge and understanding of scientific processes (Molecular Biotechnology, Organic Synthesis, Biochemistry to name a few). Her job had involved marketing of biomedical products and chemicals. From 2014, Jennifer has been an account manager looking after the Singapore branch. She also worked as the industry expert in Clinical/ Forensics and Food /Environmental for Australia, New Zealand. She had to report to USA head office and has a 70% travel schedule. In addition to the above responsibilities, she had to conduct on-site customer visits to provide technical information, product demonstrations and technical seminars. She developed business plans market analysis and sales strategies, manage and maintain information in customer database systems and attend local vendor and company sponsored trade shows.

[2] https://en.wikipedia.org/wiki/Carbendazim

Jennifer has strong organisational skills, hands on experience in chromatography, and has developed the ability to clearly present information to large groups in seminars (Questionnaire PAU 1 Table 3.4). She has developed experience in Microsoft office, and database management, in the art of negotiating, and management, and is an asset to her profession. Her perseverance in science education has paid off with a highly successful career at a very young age and from an early sheltered life. In Jennifer's opinion she has scored highest on assessing her personal traits, with a score of 15/15 in Questionnaire PAU 2, as the most influential factor towards the perseverance of her completion of her degree and her success in her further study and career development. (see Table 5.1).

Angela

Angela had initially been accepted into an engineering degree, which she later realised was not what she really wanted. She had a year off while making up her mind to try a new degree in environmental science. This late start did not hinder her in any way, in fact she was then more determined to pursue her studies in this new direction.

Angela found the technical part of the undergraduate degree most challenging especially as her second major was in spatial information science where she had to analyse maps and data. She found the practical hours inadequate and did not have the software license to practise and work from home. Her assessments were generally self-directed and required creativity, a new skill which was hard to develop in a limited time. However, by gaining work experience in this specific skill she was able to overcome this difficulty. So, what was initially her greatest challenge then became her greatest asset. She utilized her free time in university to consult with her lecturers and work at the university computers. She attributes her success to her helpful course conveners who made themselves available, and her determination to master the technological challenge. Her personal traits played a considerable role, and this is evident form her score of 15/15 on the personal traits item in Questionnaire PAU 2 Table 5.1. Her family support was particularly helpful in allowing her to persevere with her long hours. Her high school friends who kept contact with her helped her to keep a work life balance. Angela took part in extra-curricular activities such as basketball and tutoring/mentoring. In her second year at university she obtained work experience at a sustainable investment firm specialising in sustainable forestry. She was hired as an analyst to support forestry investment teams on a range of projects.

Her contract was extended from six months to three years, by which time she had finished her first degree and a Master of Science in Environmental Health degree.

Angela travelled to Europe in 2011 for three weeks and again in 2011 with friends. At present, she is working in the USA in an environment-related position.

Anita

Anita is very out-going and tended to be social and communicative with most people from an early age. This was probably because she came from a large family and her friends and her siblings' friends all became part of her cohort both in school and in university. These communicative skills which she had developed served to launch her into fame playing a lead role in a science musical which she had written during her final years in school. Her cheerful and strong personality led her to be elected as a house captain and she was admired by teachers and students alike. Anita was also appointed by her school principal to work as a debating coach, and because of this she maintained a very close contact with her school teachers and senior students for the years she was in university.

Anita balanced her studies and her social life and even worked part time in a café in a north-western suburb of Sydney. She also helped at home, looking after her younger siblings and helping with cooking dinner and doing household chores. She travelled within Australia during holidays and maintained contact with her school friends (Questionnaire PAU 1)

Anita excelled in her university degree and has won medals for her performance. Her university career was exceptional and this she attributed to self-motivation, focus and consistent hard work. She qualified as an optometrist thus fulfilling her career choice without any interruptions to her studies. Anita applied the same focussed attitude to her work right from the beginning of her career as an optometrist in Plumpton, a western suburb of Sydney from 2015. She found time amid her hectic work schedule for dedicated further study towards a doctorate in optometry. Anita's career, her outstanding university performance and her success in school examinations can be linked to her natural intellectual ability, strong personality and highly developed communicative skills.

Anita's responses to the questionnaire PAU 2 (Table 5.1) show that she felt that her personal traits were the most influential factor which helped her to complete her course. She scored 14/15 on the personal traits item.

Rita

Rita, being the second child in a family with nine children, had her fair share of household duties, in addition to her own study load. She learned from an early age, to with help at home with her younger siblings and to do household chores. Her homework was always done, according to her teachers and therefore one can conclude that she was able to balance her home duties with her school work extremely well. This personal trait no doubt proved to be an asset in her university years and this is evident from her score of 15/15 on the personal traits item in Questionnaire PAU 2 Table 5.1. This closely-knit family encouraged Rita to take part in community service through school activities. As Rita had studied in a private school for girls only and came from a family of eight girls and only one boy, she found it very hard to adjust to the co-educational group and struggled in the first year. However, the learning environment of the University of Western Sydney was very supportive, and the second-year students of the medical school played a leading role in helping the first-year students during the early months of transition. There was a sharing of resources and group study, and Rita benefitted from this team support. (Questionnaire PAU 1 Table 3.4). Rita's responses to Questionnaire PAU 2 (Figure 5.1) show that she was influenced most by her personal traits were largely responsible for her success.

Rita is a good example for students who wish to have a career and do not allow the social prejudices towards a university or a suburb deter them from the course they have chosen. During this time (2000) there were students in the school, many of them Rita's classmates, who felt that Western Sydney University was not on the same academic or social rank as Sydney University. These students preferred to do an easier course or degree from a prestigious and traditional university rather than a more difficult degree from a not so prestigious and newer university (Questionnaire PAU 1, Table 3.4).

Megan

Megan successfully completed her degree and went on to start a Masters' degree. She had always been interested in music and played the piano well. She continued to develop her music skills while she was in university. She also balanced her studies by working part-time as a pet nutritionist in the Nestle factory in western Sydney. Megan had formed firm friendships with some students in school and continued to be in contact with these school friends even though they lived a reasonable distance away from her suburb. These strong bonds of friendship with her classmates from school and the new friends she had made in university helped her to be more confident. Megan was a late developer and grew in maturity during her university years. Her contact with other students from different cultural backgrounds in Western Sydney University, and the independence she now had both with her time and travel, helped her to widen her outlook on life and focus more clearly on the paths she could take towards achieving her desire to become a veterinary doctor. Megan's parents, both being teachers, were able to guide her and advise her on her units of study choices and in general on educational and academic matters. Her family, both immediate and extended, were very supportive and encouraging with the choices she had made, and this helped her to persevere and complete her first degree. She had an older brother and older cousins all at university and she placed value on the feedback and advice she received from them regarding units of study and career option (see Questionnaire PAU1 Table 3.4).

Megan scored high on the personal traits question as being the main influential factor on her success with the family a close second influence. Her score for the personal traits item in Questionnaire PAU 2 was 13/15.

Charlotte

During Charlotte's first year she had taken up a degree in advanced science but found the physics and mathematics units quite difficult. She was intimidated by students who were in the same course and who had obviously taken part in science olympiads and had a previous knowledge of various topics in chemistry and physics. She decided not to give up a science degree but instead to change from the more difficult units to ones that she could do with greater confidence. She persevered with her studies and eventually graduated with a science degree with honours in psychology and later

completed a Masters' degree in Neuropsychology. She worked through difficult assignments by joining groups for study and took the help of tutors.

Charlotte did work during her degree years teaching refugees computer skills through a non-profit organisation in Redfern, an inner suburb of Sydney and did volunteer work at Glebe Police and Citizens Youth Centre (PCYC) teaching aboriginal children who were no longer at school. She tutored students in mathematics, science and English and worked at the K Mart department store for 10 –12 hours a week. Charlotte travelled with friends around Asia during her four-year undergraduate degree (Questionnaire PAU 1 Table 3.4).

Charlotte answered the questionnaires around the time of the completion of her undergraduate degree as she had joined the study group later. Her answers were frank and interesting. She scored high on the personal traits' questions obtaining 14/15 (Questionnaire PAU 2, Figure 5.1).

Nikolina

Nikolina enjoyed biology and geography at school and so wanted to continue study in these fields. She would have preferred to take a gap year after school, but her parents would not allow her to do so. She was a friendly and social person and her parents did not want her to become distracted from her goal to complete her degree.

She did struggle with some concepts of chemistry and mathematics in her first year. She felt that her difficulties were caused partly by the fact that she did not attend all the lectures. She did have some gaps in chemistry because she had not studied this subject in school. When she reached the second year and did not have to take mandatory subjects she did well. She made friends who were very supportive, and she realised that she was now studying subjects she really enjoyed.

She was motivated by her older brother who had studied and completed a Bachelor of Science degree earlier. She considers herself to have the traits of not quitting easily and especially when life got difficult. Nikolina took part in extra- curricular activities that included touch football, and other university games. She also volunteered in scientific trials, assisted in research, and volunteered at various on-campus activities. In addition to this, she worked at a Video and DVD store on weekends and in a medical centre for a total of 12 hours per week. She travelled to Europe for three months and

for part of her degree units she went to Kakadu, Darwin and the Great Barrier Reef. (Questionnaire PAU 1 Table 3.4).

Nikolina obtained a position working in a digital company and managed a design team at the agency, which presented its own challenges to innovative learning and work. She managed the applications and websites for clients from various backgrounds which include big corporates. They were particularly involved with the health sector. This job required a sound understanding of the ever-evolving digital environment, especially in terms of functioning requirements and systems. The position involved the actual function of apps and websites as well as undertaking client meetings, project scoping, project implementation, delivery, scheduling, reporting and documentation.
In 2015, she married and moved from Sydney to London. Responses to the questionnaire indicate that Nikolina had been strongly influenced by her friends and teachers but her strong personal traits played a leading influence on her perseverance with her undergraduate degree. Her score for personal traits was 13/15 (Questionnaire PAU 2, Table 5.1).

Xanthe

Xanthe made close friends with people in her course during her first week of university and they all supported each other through the rest of the graduate years and when working full time. She found that a lot of the basic core principles of occupational therapy were 'common sense' to her whereas to others they were not. Xanthe felt she just clicked with the main goal of the profession right from the beginning.

From Xanthe's responses to questionnaires PAU 1 (Table 3.4) and PAU 2 (Table 5.1) it is evident that her personal traits and her determination to be an occupational therapist, have been the key motivating factors, propelling her to complete her course with great energy and enthusiasm. She scored 13/15 on the personal traits item in Questionnaire PAU 2. Xanthe found the first year of the course very repetitive, with no real skills taught that could be transferrable into the field. However, in the second year she realised that the first-year course provided a foundation of principles which were needed to be innately understood to build the skills necessary for the remainder of her career. Xanthe also went into the placements with the goal of keeping an open mind and making new friends so that she could create a sort of support system while

she was away from home. Her Christian religious beliefs also helped her "stick it out during stressful and tough times". (Questionnaire PAU 1) (Table 3.4).

Xanthe spoke to other students in the years ahead of her to ask if the course continued in the same manner and rate that it did in the first year. Once she was told it would not, it made surviving the first year more manageable with the knowledge it would all be worth it in the next three years of the course.

Her family supported her throughout her whole schooling career, particularly when it came to examination time. They made it clear to her that they would be happy with whatever she chose to do and reminded her of why she had chosen the course when she had doubts during stressful periods. They were always willing to hear her accounts about her days during placement which allowed her an opportunity to debrief which she found very encouraging.

5.5 Conclusion to Objective 2

This chapter has addressed the second objective by following each participant's academic journey from school to university and beyond. The first research question of this objective asks - Does the student's performance in the School Certificate and Higher School Certificate examinations correlate with her subject choice for a degree?

Each of the eight participants studied science in Year 10 and sat for the external School Certificate examination. Their SCE science scores are reviewed in Figure 5.20

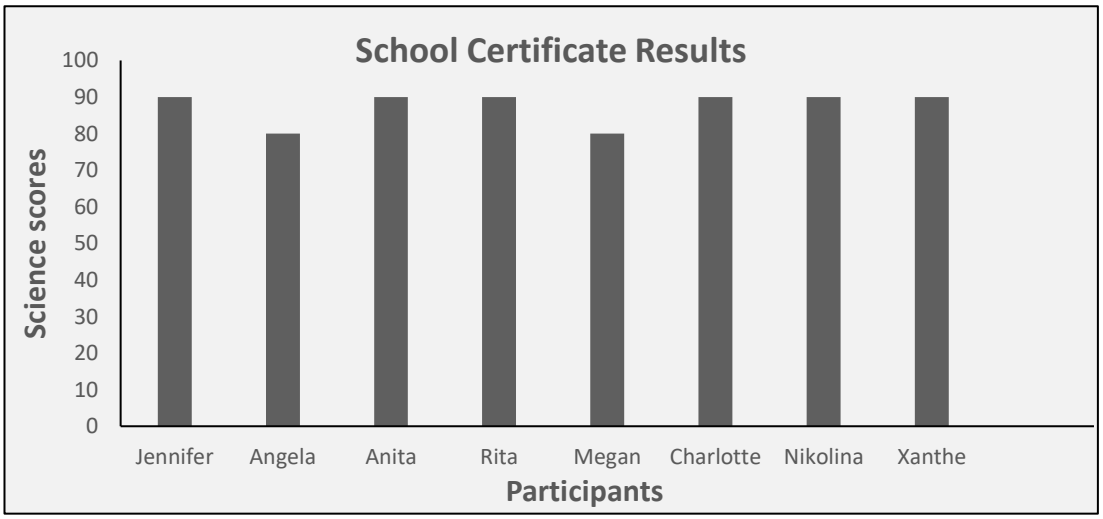


Figure 5.20 *Participant Scores: School Certificate Examination.*

All eight participants took at least one science subject for the Higher School Certificate examination. Their results in a science subject are represented in the Figure 5.21

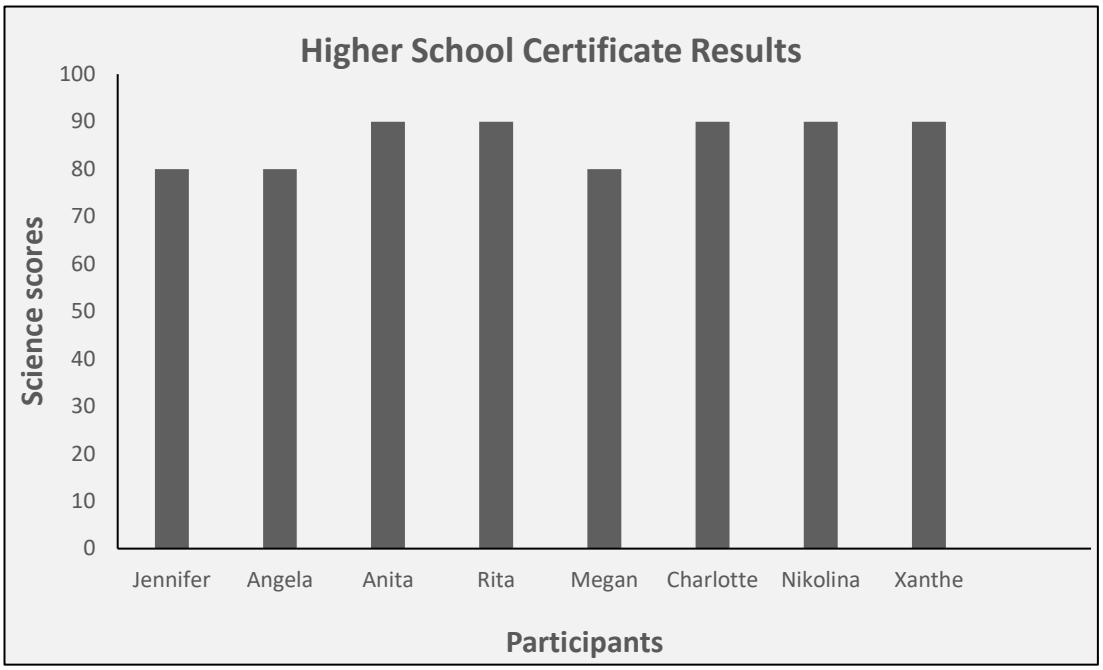


Figure 5.21 *Participant Scores: Higher School Certificate Examination.*

For these eight students the School Certificate examination is therefore an excellent grading examination that can be used to predict their performance in the Higher School Certificate examination. However, the New South Wales government has removed this examination from the school curriculum and instead introduced the highly controversial NAPLAN tests for Years 7 and 9 (Wu & Hornsby, 2012).

This comparison of a science subject results in the School Certificate (Year 10) and Higher School Certificate (Year 12) examinations show that all eight participants obtained over 80% in both external examinations. Their success in both examinations has led to a confident choice of science in university. All eight participants chose science and science-related degrees for their university courses and completed them successfully.

It is concluded that there is a link between the success of the students in the School Certificate examination, the Higher School Certificate examination and the choice of a science degree in university.

The next research question asks - What undergraduate and post graduate degrees did the participants complete successfully?

Table 5.3 is a summary of the undergraduate degrees completed successfully by the eight participants. All eight participants chose to complete a science degree. While two participants did not wish to reveal their university results for each unit of study, the other six did so and their results included high distinctions, distinctions and credits and even university medals.

Table 5.3 *Graduate Studies for the Eight Participants*

No	Case Study	Undergraduate Degree	University	Years
1	Jennifer	Bachelor of Biotechnology	Macquarie University	2007-2009
2	Angela	Bachelor of Environmental Science	Macquarie University	2010-2012
3	Anita	Bachelor of Science Optometry	University of New South Wales	2010-2014
4	Rita	Bachelor of Medicine	University of Western Sydney	2010-2014
5	Megan	Bachelor of Science (Animal Science)	University of Western Sydney	2009-2012
6	Charlotte	Bachelor of Science (Psychology)	Sydney University	2007-2010
7	Nikolina	Bachelor of Science	Sydney University	2008-2011
8	Xanthe	Bachelor of Applied Science (Occupational Therapy)	Sydney University	2011-2014

All eight participants went on to either study for postgraduate degrees or to take up professions following the successful completion of their undergraduate science degree (See Table 5.4)

Table 5.4 *Post Graduate Studies and Careers for the Eight Study Participants*

No	Participant	Postgraduate Degree	Career
1	Jennifer	Masters' Degree in Biotechnology 2010-2011	Consultant and Manager in Phenomenex, Australia and Singapore (Pharmaceuticals)
2	Angela	Masters' Degree in Science and Environmental Health, Macquarie University 2013-2015	Public Health Analyst Washington DC
3	Anita	Completing a Doctorate in Optometry	Optometrist Western Sydney
4	Rita	Internship and Residency at Westmead Hospital 2015-2016	Basic Paediatric Physician Training (BPPT) at the Children's Hospital Westmead (Western Sydney) (2017)
5	Megan	Post graduate diploma	Working in Sydney
6	Charlotte	Master's in clinical Neuropsychology 2013-2015 Doctorate	Medical Degree Notre Dame Freemantle Perth.
7	Nikolina	Post graduate diploma	Digital Company Overseas.
8	Xanthe	Ongoing specialist courses	Occupational Therapist in Sydney (Hills Private Hospital Baulkham Hills.)

In response to the second research question of this objective it is clear that all the eight particpants completed their undergraduate degrees, and went on to undertake post graduate degrees or start a career.

The third research question of this objective asks -What role did the student's personal characteristics play in helping her to conclude the degree she had started, and in some cases go on to study for post graduate degrees?

The eight participants identified personal traits as the most influential factor motivating them towards the completion of their degree. The second most influential factor was friends followed by family. The participants share common factors with their academic journeys, which were balanced with travel, sport and part-time work. The eight participants, based on the responses from questionnaire PAU 2 (see Table 5.1) have identified their own personal character and traits associated with their character such as hard work, diligence, focus and determination as the predominant reasons for their success.

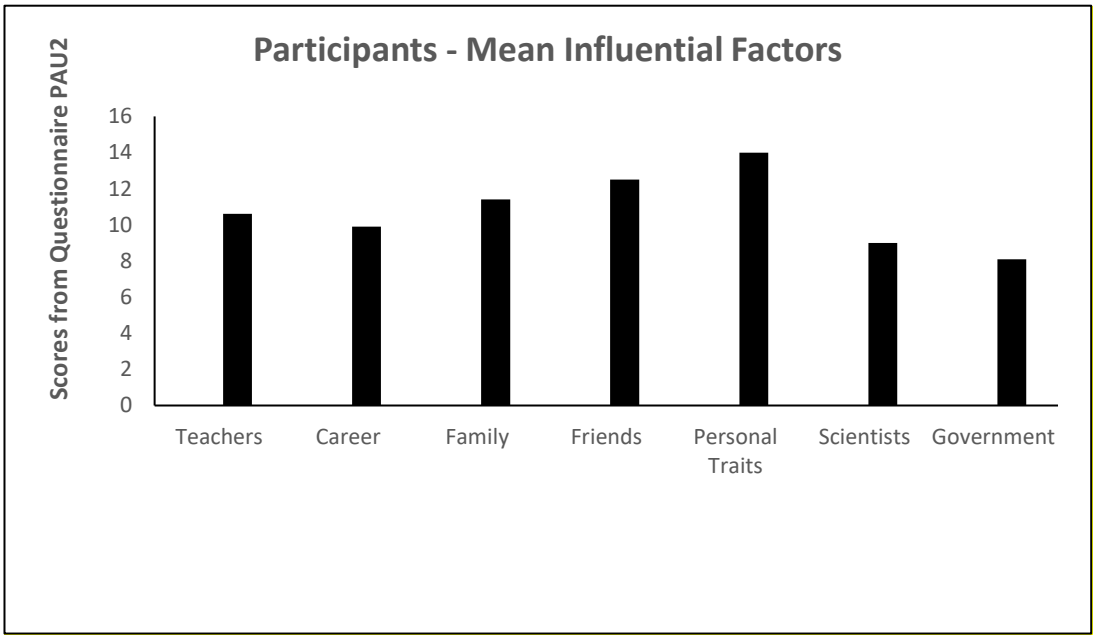


Figure 5.22 *Participant Analysis: Mean Influential Factors*

The conclusions from the three research questions point to the fact that the school external examinations acted as a foundation for the participants success in university. Their own personal strengths helped them to persevere and complete their degrees and continue to study or take up a career. The common factors are their love for science, their success in all examinations, their balanced life, and the support the received from teachers, friends and family.

CHAPTER 6

EXTERNAL INFLUENTIAL FACTORS

"Progress lies not in enhancing what is, but in advancing toward what will be."- Khalil Gibran (as cited in Fiala, 2006, p. 127).

6.0 Overview

The third objective has determined the internal and external influences on the academic progress and success of the participants. While conclusions from Chapter 5 pointed out that the participants identified their own personal traits as the main factor contributing towards their success, this chapter has identified specific external influences which have also contributed considerably towards the participants' perseverance with their studies. Data and information received from the participants themselves is of importance and is obtained from Questionnaires PAU 2 and PAU 3 to build on the initial foundations of the case studies. In this chapter information obtained from the participants' teachers (Questionnaire TQ 3) has been used to identify external and internal influences on the participants academic journeys. Finally, family members (Questionnaire M 4), have contributed towards completing the data collection by having answered the research questions stated below.

Research Questions

3a. What are the external factors identified by the participants themselves, which may have contributed towards their success in completing their academic journeys?

3b. What are the external and internal factors identified by the teachers of the participants, which may have contributed towards their perseverance in science education?

3c: What factors can the mothers of the participants identify, both within the family and externally, which can be attributed to their daughters' success in school and university?

To answer the first question of this objective which looks at the external influences on the participants academic journeys as identified by the participants themselves, Table

5.1 from Chapter 5 which displays the participant scores under relevant scale items, has been replicated as Table 6.1.

6.1 Research Question 3a: What are the external factors identified by the participants themselves, which may have contributed towards their success in completing their academic journeys?

Friends Family and Teachers were scored in this order after Personal Traits as external influences on the participants during their academic journey from school to the end of their first degree (see Table 6.1).

Table 6.1 (Same as Table 5.1) *Participant Scores for Questionnaire PAU 2 (n=8) (see Appendix E)*

Scale Item	1	2	3	4	5	6	7	8	M
Total Score	15	15	15	15	15	15	15	15	15.0
Personal Traits	15	15	14	15	13	14	13	13	14.0
Friends	13	13	12	14	12	13	12	11	12.5
Family Influence	12	12	11	13	11	12	11	9	11.4
Teacher /Mentor Influence	11	11	10	12	10	11	10	10	10.6
Career Influence	11	10	9	11	9	10	9	10	9.9
Scientists	10	10	8	9	8	9	8	10	9.0
Government	9	9	8	8	7	8	8	8	8.1

Friends

After their own personal traits, the participants identified their university friends as the next most influential motivating factor contributing towards their success. Some of these friends were new while others were school classmates who had decided to study similar courses in the same university. Participants such as Jennifer, Megan and Rita had mentioned in the interview questions PAU 1 that their friends had influenced and supported them especially when they experienced difficulties. A general view of the influence of friends at university has been made by Janice McCabe (2016), an educationist, who has studied the relationships between friends in universities and has published an article called *Friends with Academic Benefits*, in which she wrote. “The students’ friendship network types influenced how friends matter for their academic and social successes and failures” (p. 24). In this article she classified university

students into three groups. They are tight-knitters, compartmentalizers and samplers. Tight-knitters are small groups where all members are friends and they benefit from one another. They may have positive or negative effects on each other. Compartmentalizers are clusters of friends not necessarily connected across clusters and samplers were independent and not inclined to belong to a fixed group.

> Tight-knitters benefit from social support but need to watch out for friends who can distract them or drag them down academically. Compartmentalisers find balance in social and academic involvement from different clusters, and samplers appear academically successful, but often feel socially isolated. (p. 28).

McCabe concluded that "not only do supportive and academically engaged friendships help students academically and socially during college, these are relationships that are more likely to last beyond graduation" (p. 28).

All eight participants were unanimous in their agreement that their friends played a role by influencing them to continue with their course of study even when it became difficult. The questions and scores for the scale item Friends is displayed in Figure 6.1. The scoring methods including positive and negative scoring are explained in Chapter 3 and Appendix E.

Scale Item: Friends/ Respect
Q 8. I had friends in university who encouraged and helped me to persevere even when it was difficult.
Q 14. I feel that male students and teachers respect me more because I have studied science.
Q 19. I worked with my friends as a team studying together in the library, sharing resources and experiences.

Question	Jennifer	Angela	Anita	Rita	Megan	Charlotte	Nikolina	Xanthe
8	5	4	4	5	5	4	5	4
14	4	4	4	5	2	4	3	3
19	4	5	4	4	5	5	4	4
Total	13	13	12	14	12	13	12	11

Mean = 12.5 (*n* = 8)

Figure 6.1 *Questions and Scores for Item: Friends (PAU 2, see Appendix E).*

As the data obtained from the questionnaire PAU 2 demonstrated the fact that the friends of the participants had played a considerable supporting role in helping them to persevere with their studies. This is obvious from the mean score of 12.5/15. The researcher developed a short questionnaire called Participants at University 3 (PAU 3), to obtain further information about peer support. The researcher asked each participant to answer six questions using email to determine specific ways in which peer support had helped them on their academic journey.

The following questions were asked in Questionnaire PAU 3 (Appendix H).

1. Do you work within a study group at university or do you do most of your study individually?
2. Do you share resources? Are you classmates generous with resources?
3. Have you used the method of peer assessment or self -assessment with your assignments?
4. Do your friends discuss your/ their goals for study or career?

5. How often do you meet your university friends socially? Do you keep contact electronically?
6. Do you discuss strategies for dealing with difficulties and obstacles to your study?

Support within study groups was influential as was peer criticism. With electronic communication so readily available and used by young people, advice discussions and suggestions among peers was given via text messages and email. Below is a summary of the answers of most of the participants to the researcher's request for further information.

Friends influenced the students in the following way-

1. They received encouragement through dialogue with their friends especially when doubts about the course arose while they were halfway through their degrees.
2. They received support within study groups. Friends were generous with the sharing of resources. Male students were generally more generous than female students.
3. Peer criticism was positive and given only when requested. This was beneficial.
4. Fiends played a big role in directing them towards the goals of success in examinations, the achievement of the degree and the opportunity for a career.
5. They had contact by email text messages and phone conversations. Only a few met university friends socially. Most meetings were held in university libraries.
6. There were ongoing discussions about the problems they experienced while in university. Participants found that older students were very helpful in recounting how they had overcome difficulties, thus giving examples of strategies for coping with similar problems. Rita and Megan who attended Western Sydney University felt that they had experienced a strong support system when they were first year students.

Family

The eight participants all identified the family support they had received during their studies as very important to substantial. Figure 6.2 shows the participant scores on the scale item Family.

Scale Item: Family

Q 3. I have had discussions with my parents about my choice of science subjects for the HSC.

Q 4. My brothers and sisters did influence my choice of subjects for the HSC and for university.

Q 12. My mother's managerial skills at home/ at work outside the home encouraged me to better myself with my studies using the opportunities available at that time.

Question	Jennifer	Angela	Anita	Rita	Megan	Charlotte	Nikolina	Xanthe
3	4	4	4	5	4	5	4	5
4	4	4	3	3	3	3	3	2
12	4	4	4	5	4	4	4	2
Total	12	12	11	13	11	12	11	9

Mean = 11.4 (n = 8)

Figure 6.2 *Questions and Scores for Scale Item: Family (PAU 2, see Appendix E).*

Teachers/ Mentors

In February 2005, Harvard University set up two task forces, one for Women in Science and the other for Women in Science and Engineering to encourage the advancement of women in these faculties (Ribu, 2007). This was because the university had made limited progress until then to create a genuinely diverse faculty. The report identified problems for women in science at that time due to the lack of support and encouragement and recommended that departments invite women to give departmental seminars. The presence of female convenors at scientific symposiums has correspondingly produced more female speakers. (Casadevall & Handelsman, 2014). Therefore, it has been suggested by the researchers that one mechanism for achieving gender balance at scientific meetings was to involve more women as convenors. Recent research on mentoring support for early undergraduate women, (Hernandez et al., 2017) showed that the women benefit from mentoring and that their scientific identity and interest in science careers was strengthened.

The eight participants were influenced by their science teachers in school and their tutors in university though to a lesser degree than friends and family. Their responses to initial questionnaires suggested that female mentors did play a significant role in encouraging them to study science. Questionnaires PAU 1 and PAU 2 were used to find out the influence of tutors and tutor mentors, both male and female, on the individual students during their early years in university.

Scale Item: Teachers/Mentors
Q 1. I have been influenced by my school science teachers to take up a science subject for the HSC.
Q 2. I have been influenced by my teachers and career advisors to take up a science/ science related degree.
Q 5. My tutors/ mentors at university played an active role in helping me to complete the degree I had chosen.

Question	Jennifer	Angela	Anita	Rita	Megan	Charlotte	Nikolina	Xanthe
1	5	4	4	4	3	4	5	4
2	3	3	3	4	3	3	2	4
5	3	4	3	4	4	4	3	2
Total	11	11	10	12	10	11	10	10

Mean = 10.6 (n = 8)

Figure 6.3 *Questions and Scores for Scale Item: Teachers/Mentors (PAU 2, see Appendix E).*

Career Opportunities

Career opportunities and recent innovations in science may have spurred both male and female students to continue to study science even at postgraduate level. From the scores in Table 6.1 the influence of career opportunities does not seem to be very strong for the eight participants except for Jennifer and Rita who scored 11/ 15 on this scale item. It could be said that at the time the participants answered the questionnaire they were still many years away from taking up a career and so were not very strongly influenced by career opportunities or the job market at that time. Even Anita and Megan who had definite careers in mind (that of an optometrist and veterinary doctor) have scored low on this item with a total of 9/15. It could be that they were so sure of the career they wanted that they felt that other science careers did not influence their decisions.

Scientists

Based on the data collected from Questionnaire PAU 2, Jennifer, Angela and Xanthe have been moderately influenced by scientists in Australia and the world. It is possible that other influences such as the teachers and the family served as greater influences on the participants whose scores of under 10 demonstrated that their interest in science was not related in any way to the influence of a scientist while they were at university. Therefore, for this study, the role of the scientists, both past and present, is inconclusive in attempting to view their influence on the students' choice of subjects or success.

The Government

Data from Table 6.1 show a low mean score of 8.1/15 on questions relating to the government influence. One of the statements under this scale item was-

"I feel that there is a direct link between the jobs available for science graduates and the government support for science in schools and universities".

All the participants except Rita were undecided on this statement achieving a mean score of 3/5. The present government, led by Malcolm Turnbull, aims to put science and scientific innovations high on his agenda. This new focus by the government may play a role in influencing science students of the present and future. However, for the eight participants in this study the government influence during their school and university years has been minimal.

In conclusion to the responses made by the participants in Questionnaire PAU 2, the strongest external influences have been university friends, the family and teachers and mentors.

6.2 Research Question 3b: What are the internal and external factors identified by the teachers of the participants, which may have contributed towards their perseverance in science education?

Teacher Questionnaire TQ 3 (See Appendix F)

This questionnaire was designed to respond to the second research question 3b attempting to identify the teachers' perceptions of the external factors influencing the student participants' academic journey. Four teachers answered the questionnaire for seven of the eight participants. The scoring method is described in detail in Appendix F.

This questionnaire used the same scoring methods as TOSRA and PAU 2, but these scores were determined for the four teacher responses with the intention of obtaining more information about the participants to add detail to each case study and not for any measured calculation. The numerical calculation allows for identification of the stronger and weaker influential factors using the same scale items as TOSRA and PAU 2.

The scores of the teachers including the mean scores are also recorded in the figures. The maximum score for each scale item was 25. The sum of the four-teacher score for each scale item was therefore 100 and could be considered as a percentage score. The questions for the scale items and scores for the first three influential factors Personal Traits, Family and Careers (as identified by the teachers) have been represented by Figures 6.4, 6.5 and 6.6. For the lesser influential items such as Teachers and Friends (as identified by the teachers) a descriptive response replaces the numerical data and is included in the literature discussion of each participant.

Personal Traits

Teachers scores identified Personal Traits as the strongest influential factor for the participants. Figure 6.4 represents scale item questions and the total and individual scores made by the four teachers for each of the participants.

Scale Item: Personal Traits
Q1. This student was motivated to take up science in Years 11 and 12 due to a love for science.
Q 8. This student's intelligence played a role in her success in the HSC and her university studies.
Q 9. This student made a consistent effort with her studies and her success in completing her degree is largely due to her hard work.
Q 10. This student was confident, and this personal trait has helped her to succeed in completing her degree.
Q 11. This student showed the ability to manage her studies and a part time job and household duties well without getting stressed.

Teacher	Jennifer	Angela	Anita	Rita	Megan	Charlotte	Nikolina	Xanthe
Mrs A	23	21	25	24	20	N/A	19	25
Mrs G	23	22	24	25	16	N/A	19	22
Mrs F	22	22	17	23	17	N/A	18	22
Mrs S	25	20	23	24	20	N/A	19	21
Total 100	93	85	89	96	73	N/A	75	90

Mean = 86 (*n*= 7)

Figure 6.4 *Questions and Scores for Scale Item: Personal Traits (see Appendix F).*

The responses of teachers to specific questions on participants' personal traits show that Jennifer, Anita, Rita and Xanthe achieved cumulative scores in the range 89- 96 indicating that their success as perceived by their teachers was due to their character and strengths. Angela, Megan and Nikolina achieved good scores in the range of 73-

85 indicating that their personal traits did have a strong influence on their success, but not to the same extent as the other four participants.

Teachers knew the students well and identified this scale item as the strongest internal influential factor. This reinforces the fact that the participants themselves identified this very scale item as the strongest influence on their success. The scores obtained for specific personal traits such as diligence, confidence, balance attitude and intelligence which were identified from the corresponding questions 1, 8 9, 10 and 11 in questionnaire PAU 2 are recorded in Table 6.2

Table 6.2 *Sum of Four Teacher Score on Specific Questions defining Personal Traits (see Appendix E)*

			Specific Personal Traits			
Participant	Total	Attitude	Intelligence	Diligence	Confidence	Balance
		Q 1	Q 8	Q 9	Q 10	Q 11
Jennifer	20	19	19	19	20	16
Angela	20	17	17	18	18	15
Anita	20	17	18	17	19	17
Rita	20	19	20	20	19	18
Megan	20	14	11	19	14	15
Charlotte	20	N/A	N/A	N/A	N/A	N/A
Nikolina	20	14	14	15	17	15
Xanthe	20	19	18	20	18	15

Note: Each question had a maximum score of 5. Four teachers have scored each participant on each question. The sum of the four-teacher score is represented in this table.

Family

Based on responses to the early questionnaires such as PAU 1, the role of the family was beginning to emerge as an important influence on the participants. The participants identified the family influence as the third strongest from questionnaire PAU 2. Similarly, the four-teacher score demonstrated that the family influence is very strong. Figure 6.2 includes the scale item questions and the corresponding scores. The teacher responses show that Jennifer, Angela and Rita, with scores in the range 85-88, were very strongly influenced by their families. Anita and Nikolina were

influenced less by their family members. Figure 6.5 shows the questions which relate to the family item and they also include the scoring method. Positive scoring and negative scoring methods are explained in Appendix F.

Scale Item: Family
Q 6. This student was strongly supported and encouraged by her family members.
Q 7. This student's mother had a career outside the home, and this served as a motivating factor for her to complete a degree and to have a career.
Q 16. This student's cultural background will restrict her from certain courses and careers.
Q 18. This student's family will not encourage her to take up a science degree or career.
Q 24. Family issues related to financial difficulties or poor health of parents may cause this student to give up her studies and help at home.

Teacher	Jennifer	Angela	Anita	Rita	Megan	Charlotte	Nikolina	Xanthe
Mrs A	25	22	18	22	23	N/A	20	21
Mrs G	20	22	17	23	19	N/A	18	22
Mrs F	20	20	14	20	20	N/A	18	20
Mrs S	20	23	19	23	21	N/A	21	20
Total 100	85	87	68	88	83	N/A	77	83

Mean = 82 (n = 7)

Figure 6.5 *Questions and Scores for Scale Item: Family (see Appendix F).*

Career

The participants did not rate career opportunities very highly based on their responses to Questionnaire PAU 2 (see Table 6.1). However, the teachers did rate careers as the third most important influential factor on the participants perseverance with science education. Figure 6.6 includes the scale item questions and the teacher scores.

Scale Item: Career
Q 2. This student was motivated to take up science in Years 11 and 12 with the hope of receiving good results, taking up a science degree in university and obtaining a good job.
Q 12. This student was interested in a science-related career when she was in school.
Q 17. This student may complete her science degree but is not likely to take up a science related- career.
Q 20. This student has the potential to take up a science career and may do so but only for a short time. She is not likely to continue once she gets married and has children.
Q 23. This student does not fully understand the true implications and demands of a science career.

Teacher	Jennifer	Angela	Anita	Rita	Megan	Charlotte	Nikolina	Xanthe
Mrs A	25	20	20	22	20	N/A	18	22
Mrs G	23	20	20	24	17	N/A	14	20
Mrs F	20	17	20	23	16	N/A	18	22
Mrs S	20	19	20	23	20	N/A	19	20
Total 100	88	76	80	92	73	N/A	69	84

Mean = 80 (n = 7)

Figure 6.6 *Questions and Scores for Scale Item: Career (see Appendix F).*

Teacher scores indicate that they considered Rita and Jennifer to be highly motivated by career choices. Rita went on to become a doctor and Jennifer obtained an important position in a large biomedical company- Phenomenex. The next two highest scores for

the scale item career were given to Anita and Xanthe. Anita is currently an optometrist and Xanthe an occupational therapist. Based on the data from the Questionnaire TQ 3 it can be inferred that the teachers identified the students' personal characteristics as the most important influence on their progress and success. The family support which the participants received during their university years and the goal of a successful career at the completion of the degree were perceived by the teachers to be the strong external influences on the participants. The literature which follows draws on the details from the questionnaire responses using some mean and individual scores to reinforce statements.

Jennifer

Teacher responses to Questionnaire TQ 3 shows Jennifer with a score of 93 for personal traits indicating that her teachers considered that Jennifer was a strong character. She had been motivated to take up science in school due to a love for science and career opportunities and this is reflected with a score of 88 for that scale item. The teachers considered that Jennifer had been supported by her family, especially her mother who worked in the same school. They believed that her hard work and confidence helped her to succeed. They did not score her friends' influence on her as very highly.

Angela

Teachers responses suggested that Angela was strongly influenced by her family members especially her parents and this is reflected with a score of 85 for that scale item They considered that career opportunities might influence her slightly but that her calm and balanced character played a role in her persevering and succeeding in completing her degree. They did not consider that they as her mentors or her friends had a strong influence on her.

Anita

Teachers responses show that they considered that Anita's intelligence, confidence and attitude towards science were the key factors responsible for her success. They thought that they had played a significant role in helping her to continue with the study of science, as she had sought advice while she was at school and had maintained contact with her teachers while she was at university. Anita's responses to their advice

had always been positive and she stated that it was their encouragement which made her realise that she could follow in her father's footsteps and become an optometrist like him although she was a female. They felt that career opportunities were important to her giving her a score of 80 for that scale item.

Rita

Teachers' responses to Questionnaire TQ 3 show clearly that she was highly intelligent, hardworking and focussed on a successful career. All four teachers knew Rita's family well and were impressed by the support the siblings gave each other. They were particularly impressed by the calmness of Rita's mother who gave individual attention to each of her many daughters. (Scale Item Development-observations and discussions Chapter 3). Rita's siblings who studied in the same school. Her strong individual traits were considered an influential factor in helping her to succeed. Her score of 96 is the highest score given by the teachers for the seven participants on Personal Traits.

Megan

Teachers' responses giving Megan a score of 83 for family influence demonstrate the fact that Megan's family played a strong supporting role in helping her to choose her degree and complete it successfully. As Megan had been in the school for Years 11 and 12 only, a short time as compared to the other participants, the teachers did not consider that they had influenced her strongly with the decisions she made and. The teachers' responses show that they believed that career opportunities would influence Megan in her choice of subjects as she had always wanted to become a veterinary doctor.

Charlotte

Charlotte came from a different school and therefore there is no evidence to suggest the influence of teachers on her decisions.

Nikolina

Teachers who answered this questionnaire knew Nikolina's family well as her mother worked part- time in the same school. Their responses gave Nikolina very mediocre scores for all five items with the family influence the highest score of 77 followed by personal traits with a score of 75. They perceived that friends, with a score of 71,

would be the next most important influence on Nikolina helping her to pursue and complete her studies.

Xanthe

Responses show that the teachers considered Xanthe's intelligence and diligence to be the most important factors directing her towards success in school, university and her occupation as she was scored 90 on Personal Traits. Xanthe had discussed career opportunities with her science teachers and was open to suggestions from them so their score of 84 for this scale item is reasonable. Her family influence, as responses demonstrate, with a score of 83, were considered by the teachers to be stronger than the teacher's influence in her choice of subjects for school and university.

6.3 Research Question 3c: What factors can the mothers of the participants identify, both within the family and externally, which can be attributed to their daughter's success in school and university?

Mothers of the participants took part in this study by responding online to the questionnaire designed to elicit information from them about their attitude and contribution to their daughter's academic journey. Questions were addressed to obtain information about the mother's perception of other external factors which could be linked with their daughter's success. The same method of scoring was used for TOSRA and PAU 2, and the scale items were similar. Questions had positive and negative scoring methods (see Appendix G). The Questionnaire M 4 comprised 24 questions though only 21 were used for scoring. Questions 5, 6 and 7 were written to obtain information about whether the mother worked outside the home full time, part time or in the home. These questions were for classification and did not carry scores. The remaining questions carried scores and have been grouped by scale items such as Family Support, Balance, Teacher Influence and Career Opportunity. Scale Item Family Support had 6 questions, while the other three scale items had 5 questions each. Therefore, final scores were recorded as percentages for comparison. Scores were used to elicit information. Appendix G contains the questions 1- 24.

There are many discussion and debates about the influence of working mothers compared to stay-at-home mothers and the effect this may have on families (Boyd &

Leatherby, 2014). It is quite likely that researchers and others will continue to talk about this comparison between stay-at-home mothers and working mothers and the advantages and disadvantages of the families they look after. It is equally likely that there will be evidence to support both parties. Some researchers have claimed that working mothers will encourage their daughters to work full-time and thus be more successful in the corporate world. For example, research by McGinn, Ruiz Castro, and Long Lingo (2015) in an article entitled *Mums the Word! Cross-national Effects of Maternal Employment on Gender Inequalities at Work and at Home* tested the association between children who were raised by an employed mother on the outcomes at work. Based on data gathered from an International Social Survey Programme in 2002 and 2012 from men and women in 24 countries they found that:

> Adult daughters of employed mothers are more likely to be employed, more likely to hold supervisory responsibility if employed, work more hours, and earn marginally higher wages than women whose mothers stayed home fulltime. (p. 8).

Mothers of participants Jennifer, Angela, Megan and Charlotte worked full-time. Mothers of participants Anita and Rita were stay-at-home mothers with large families. Mothers of Nikolina and Xanthe worked part-time. Therefore, the participants' mothers could be representative of a broad range of mothers in society today and did not belong to any specific group. Hence the mean assessment of their responses to the questions is more likely to be authentic and unbiased. However, based on recent findings by researchers about parental involvement in academic success of university students, there is a positive relationship between parenting style and undergraduate student success and between parental influence and undergraduate student success (Donat, 2015). This is the link the researcher attempted to find between the mothers and their involvement in their daughters' academic progress. The Questionnaire M 4 has positive and negative scoring questions allocated to four scale items - Family Support, Balance/Stress, Teachers/Education, and Career Opportunity (see Appendix G for all 21 questions and scoring methods). Some sample item questions and participant scores have been reproduced in Figures 6.7. 6.8 and 6.9. Figure 6.7 gives the responses of the eight mothers of the participants to the questions under the item Family Support. Similarly Figure 6.8 displays details of the responses to the item Balance/ Stress, and Figure 6.9 displays details of the mother's responses to the item

Teachers/ Mentors. The last item Careers has not been displayed because it scored the lowest as an influential factor. In Figure 6.11 all the responses made by the mothers of the participants to the four scale items have been represented graphically.

Scale Item: Family Support

Q1. I have had a discussion with my daughter before I signed her form for subject selection for the Preliminary (Year 11) and the Higher School Certificate (NSW).

Q2. I have encouraged her to take up at least one science subject in school.

Q8. During the Higher School Certificate and university examination periods I gave my daughter extra emotional support.

Q10. I was interested in the course she had chosen and discussed with her the job prospects which would be linked to her degree.

Q12. My managerial skills at home/ at work outside the home served as a role model for my daughter and gave her added confidence in herself.

Q14. My husband fully supported my daughter in her choice of subjects and the completion of her degree.

Question	Jennifer	Angela	Anita	Rita	Megan	Charlotte	Nikolina	Xanthe
1	5	4	4	4	5	4	4	5
2	5	4	4	4	4	4	4	2
8	5	4	4	4	5	5	3	4
10	5	5	4	4	5	4	3	4
12	5	5	4	3	5	4	3	2
14	5	5	5	4	5	4	4	5
Total 30	30	27	25	23	29	25	21	22

Mean = 25 (n = 8)

Figure 6.7 *Questions and Scores for Scale Item -Family Support (see Appendix G)*

Scale Item: Balance/ Stress
Q9. I expected my daughter to fulfil her household duties during all examination periods.
Q11. I was concerned about whether my daughter would cope with the level of difficulty in her degree.
Q16. My daughter was unable to continue with part time work during the examination period.
Q17. My daughter showed signs of stress leading up to all examination periods during school and university.
Q24. My daughter was confident and able to organise her studies and her recreation/ part time work well.

Question	Jennifer	Angela	Anita	Rita	Megan	Charlotte	Nikolina	Xanthe
9	4	4	4	4	2	5	2	4
11	5	4	4	4	5	4	5	5
16	4	4	5	4	3	4	3	4
17	5	3	3	5	3	3	4	3
24	5	5	4	4	4	4	4	4
Total 25	23	20	20	21	17	20	18	20

Mean =20 (*n*= 8)

Figure 6.8 *Questions and Scores for Scale Item -Balance/ Stress (see Appendix G).*

Scale Item: Teachers/ Mentors
Q3. I was pleased with the level of science teaching in school and with the practical lessons as well.
Q4. I felt that there should be a bridging gap between the Higher School Certificate examination and university science degrees.
Q18. I felt that my daughter had received adequate information in school about science degrees and science careers.
Q21. My daughter had to learn how to reference using APA / Harvard in university as she had not been taught this is school.
Q22. The teachers in school and university were very supportive and motivated my daughter to do her best.

Question	Jennifer	Angela	Anita	Rita	Megan	Charlotte	Nikolina	Xanthe
3	5	5	4	4	4	4	5	4
4	1	4	2	4	4	4	3	4
18	5	4	4	4	4	4	3	4
21	2	4	4	4	2	2	2	2
22	5	4	5	5	4	5	4	5
Total=25	18	21	19	21	18	19	17	19

Mean = 19 (*n*= 8)

Figure 6.9 *Questions and Scores for Scale Item -Teachers/ Mentors (see Appendix G)*

Jennifer

Jennifer's mother worked in the same school though not as a teacher but as an administrator. She felt that her family support for Jennifer had been very strong (see Figure 6.7). Her responses also suggest that she identified Jennifer's ability to deal positively with stress and thereby balance her studies and her life as a contributing factor towards her success (see Figure 6.8). Jennifer's mother placed career interest above teacher influence for her daughter.

Angela's mother also considered that her family support towards her daughter was the strongest influence on her daughter's academic journey and success (see Figure 6.7).

She placed a high value on the school, the education system of that period and teachers of the school in the supporting role they had played in her daughter's academic life. (See Figure 6.9). Angela's mother felt that the career interests and her daughter's personality had a strong influence on her decisions as well.

Anita

Anita's mother believed that the family had played the strongest role in supporting her daughter. The fact that her daughter had followed her husband in his profession demonstrated family involvement with decision making. However, she gave high scores towards her daughter's personal traits as being influential factors towards her success (see Figure 6.8).

Rita

Even though Rita's teachers had voted her family as the strongest influence on her, surprisingly Rita's mother did not seem to think so based on her responses to the questions (see Figure 6.7). She identified her daughter's character and her ability to balance her work and stress as the strongest contributing factor to her success in completing her medical degree (see Figure 6.8). She also rated highly the teachers and the education system as positive contributing factors allowing her daughter to succeed in the career she had chosen.

Megan

Megan's mother worked in the same school and she believed that family support was the maximum influence on her daughter's choice of a degree and her success in the completion of the degree (see Figure 6.7, Score 29/30). Her responses pointed to the influence of the education system and teachers in the school as the next most influential factor. Megan's mother did not, at the time she responded to the questionnaire, rate her daughter's personal traits or her career goals as strong influential factors.

Charlotte

Charlotte was from a different school, but her family background was similar. Her mother rated the questions related to the family support structure as being most important for her daughter's progress (see Figure 6.7, Score 25/30). She placed her

daughter's character and determination as the next most influential factors towards her academic success, followed by education system and teacher motivation.

Nikolina

Nikolina's mother rated her daughter's strong character and her ability to cope with stress as the most influential factor contributing towards her success (see Figure 6.8). The second most important contributing factor was the family support given to her daughter throughout her life but especially during her university years. Nikolina's mother did not rate the education system, teachers or career goals as strong influences on her daughter.

Xanthe

Xanthe's mother rated her daughter's ability and strength of character as the most influential factor towards her success (see Figure 6.8, Score 20/25). This agrees with what the teachers of the school had identified for Xanthe. However, Xanthe's mother identified the teachers and the education system as the next most important influence (see Figure 6.9). The teachers had identified the family influence as more important for Xanthe's academic success compared to their influence. Xanthe's mother did not believe that a career was the motivating factor for her daughter's success.

A summary of the responses made by the mothers of the participants and the mean scores is presented in Table 6.3 The mean responses in the table demonstrate the fact that all the mothers of the participants felt that they had played an important role in supporting their daughters through school and university and in the choices, they made. The mothers also responded with the firm belief that their daughters were able to cope with the pressures of university life and lead a balanced life without getting stressed. The education system, teachers and career opportunities, appear of secondary importance, as compared to family influence and student character.

Table 6.3 *Responses from the Parent Questionnaire M 4 (see Appendix G)*

Scale Item	Mean Score
Family Support	84%
Balance/ Stress	80%
Teachers/ Education System	76%
Careers	68%

Note: Graphical representation in Figure 6.11

6.4 Conclusion to Objective 3

The first research question asked- What are the external factors identified by the participants themselves, which may have contributed towards their success in completing their academic journeys?

The responses of the eight participants to Questionnaire PAU 2, identified their perception that their personal traits were the main reason for their success in completing their degrees. The participants' friends in university, family members and finally their teachers and mentors also played a significant role in motivating and encouraging them along their academic journey (see Figure 5.22)

The second research question asked-What are the external and internal factors identified by the teachers of the participants, which may have contributed towards their perseverance in science education?

The teachers' response to the Questionnaire TQ 3, identified the participants' personal traits as the most important factors responsible for their success. These personal traits were a positive attitude, intelligence, diligence, confidence and the ability to balance their studies with their everyday activities. Teachers attributed importance to the family support that the participants received while they were in school and university. Teachers also inferred through their responses to the questionnaire that the choice of subjects and degrees taken by the participants were linked with career opportunities. They considered that career goals were also a strong external influence on the participants.

Teachers' mean scores identified personal traits for the eight participants as the main factor contributing to their success in completing the undergraduate degree (see Figure 6.10 and Appendix F).

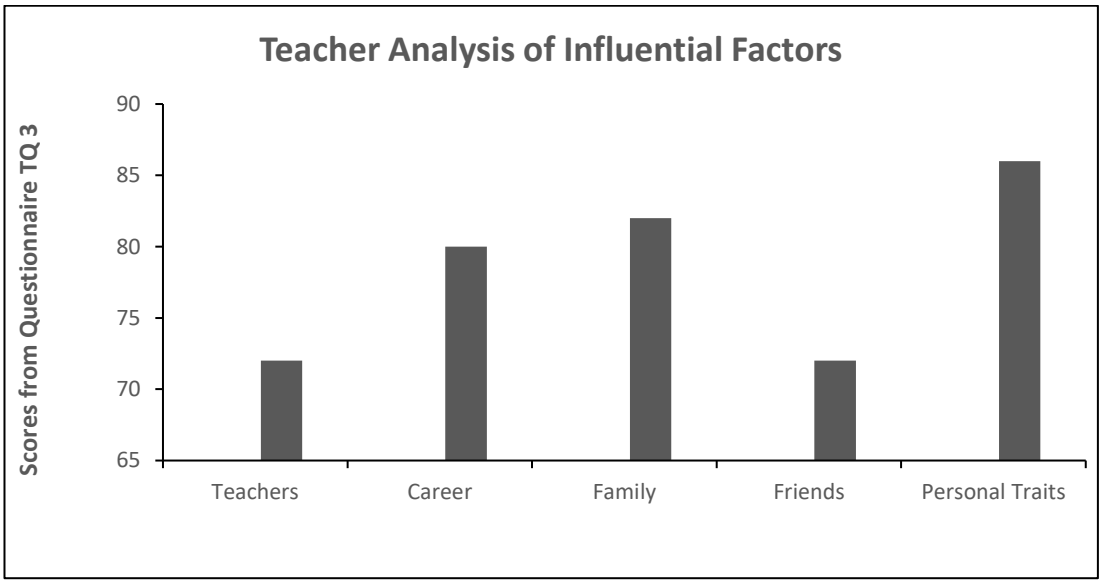


Figure 6.10 *Teacher Analysis: Mean of Influential Factors.*

The third research question asked- What factors can the mothers of the participants identify, both within the family and externally, which can be attributed to their daughters' success in school and university?

Mothers of the participants felt that the family support their daughters received during their school and university years contributed largely to their success in persevering and completing their degree (see Questionnaire M 4). Their daughter's ability to balance studies and daily activities and cope with stress was the next most influential factor contributing towards success.

The mothers of the participants identified the family as the strongest influence on their daughters' academic progress followed by personal traits, teachers and career opportunities (see Table 6.3). Figure 6.11 represents the details of this table. The scores are the mean scores for all the eight mothers for each scale item (see Appendix G).

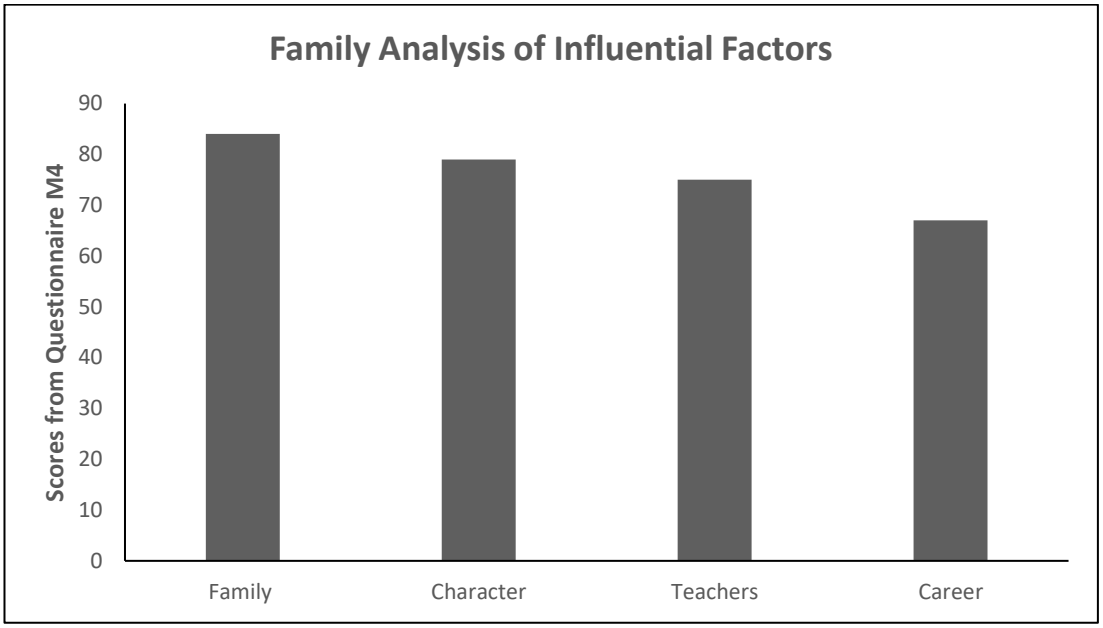


Figure 6.11 *Parent Analysis: Mean of Influential Factors.*

The emergent theory based on the conclusions of observations, discussions, questionnaires and interviews is that the most compelling influence on the participants has been their own individual personal character. The participants varied in intelligence and talents, there was a variety even in the science and science- related degrees they completed, yet the common thread which bound them together was the ability to persevere and complete the degrees they had chosen. This is attributed to their strength of character which family members, friends and teachers have helped to develop over the years.

CHAPTER 7

CONCLUSIONS LIMITATIONS AND RECOMMENDATIONS

"Permanence, perseverance and persistence in spite of all obstacles, discouragements and impossibilities: It is this, that in all things, distinguishes the strong soul from the weak." - Thomas Carlyle (Carlyle as cited in Duffield, 2009, p.190).

7.0 Overview.

In the three preceding chapters, the data and information obtained from the eight case studies has been used to develop theory thus using the framework of the grounded theory. Each chapter which connected with each objective had the three research questions answered at the conclusion. These conclusions have been based on the data analysed. The eight participants have had their academic lives documented in such a manner as to allow the reader to get to know them and be part of their academic journey. The conclusions at the end of each chapter, made by the researcher, should also be the conclusions of the reader, thus visualising and comprehending the patterns and connections between the eight case studies. This chapter has consolidated the emergent theory which has arisen and has used this theory as evidence for a final analysis of the study. This chapter has also defined the limitations of the study and has made recommendations for science education.

7.1 Analysis of Case Studies

The eight participants, though different individuals, had a lot in common as they made their subject choices and went on their academic journey through university. Yet there were differences within the group as well. A review of the similar and different aspects of the participants academic journeys as observed and identified by this longitudinal study is recorded below.

Personal Traits

All eight students could be considered to have strong personalities, identified by their mothers or teachers from Questionnaires TQ 3 and M 4, and this is the most common factor which has contributed to their choice and completion of a science or science-related degree. They were all able to balance their studies with part-time work and

even overseas travel (see Table 3.4, Questionnaire PAU 1). They showed a common interest in science from their school days scoring well on the science attitude questionnaire TOSRA, particularly on scales such as Enjoyment of Science Classes and Attitude to Scientific Inquiry (see Figures 4.1 and 4.2). All eight participants scored a Band 5 or Band 6 in a Science subject in the School Certificate and Higher School Certificate external examination (see Figure 5.20 and 5.21). In addition to this all the participants competed their first undergraduate degree without much delay after completing school. (see Table 5.3). Some participants went on to study for other degrees while others found immediate employment. Seven participants are currently employed (see Table 5.4) and one participant is still studying for her fourth degree.

Friends

All eight participants were unanimous in their responses to Questionnaire PAU 2 demonstrating that their friends had supported and encouraged them to persevere and complete their degrees. The influence of university friends on the participants is clearly a dominant factor (see Questionnaire PAU 3 and Figure 5.22) and has proved to be the second most influential factor identified by the participants themselves.

Family

While many of the students had mothers, who worked outside the home, others had mothers who did not. The students' relationship with their mothers was strong and the mothers themselves were directly involved with their daughter's choice of subjects forthe HSC and University (see Questionnaire PAU 2 and M 4). Some mothers expected their children to carry out household tasks while others gave them additional support during examination periods. In all eight case studies it became clear that the students came from very stable homes with both parents showing interest in their choice of subjects in school and their progress with the science-related units in university. Therefore, family support and stability can be a deciding factor contributing to the success of the students and the completion of the degrees. While some mothers felt that their managerial skills may have played a role in their daughter's success others did not (see Questionnaire M 4 in Appendix G). Responses from mothers show that they felt that the participants' personal traits were almost as important as the family support in contributing to the participants overall success in completing their degree. (Refer to Figure 6.11).

School Teachers

The four schoolteachers considered that the participants had been influenced by their families and that their own personal traits could be largely attributed to their success. They all agreed that the participants' confidence, diligence attitude, intelligence and ability to deal with stress were contributing factors responsible for developing perseverance in science education. (see Appendix H). The teachers considered that career opportunities were also a motivating factor spurring on the participants to complete their degrees. (see Figure 6.10).

Socio-economic Background

Seven participants lived in the North West suburbs of Sydney and one in the South West of Sydney. They hailed from families where at least one parent worked and could be upper middle class in terms of their socioeconomic background. The parents were well educated and sent the daughters to a private school except for one who went to a selective government school. All eight participants attended single sex education schools.

Attitudes towards Science

As seen from early attitude responses (see Figures 4.1 and 4.2) and individual responses to questionnaires all eight participants had a positive attitude towards science and science education, and this has been a motivating factor helping them to complete their degrees.

External School Examinations

All eight participants scored very well in Science in the School Certificate and Higher School Certificate examinations (see Figures 5.20 and 5.21). These consistent results are a common factor and display the participants' ability to perform well in external academic examinations.

Family Size

Participants were from very small families as well as from big families. So, though the family played a major role in supporting the participants, the size of the family and the various siblings did not contribute nor detract from the participant's success.

Career Choice

Some participants took up careers related to their undergraduate degrees and others did not. Careers were varied. One participant is still studying for her fourth degree. Some went on to study for post-graduate degrees while others competed diplomas and specialist studies (see Table 5.4).

Cultural Background

While all the participants were born in Australia, they were from different cultural backgrounds, and some of their parents had been born overseas (see Questionnaire PAU 1 Table 3.4 and Appendix D Memo). Their cultural backgrounds did not stand out as a controlling or motivating factor towards their success.

A summary of the conclusions for the three objectives is displayed in Figure 7.1

Objective 1 Science Attitudes and Interests	Objective 2 Academic Journeys	Objective 3 External and Internal Influences
School Environment and Teaching Strategies	Success in External Examinations	Teachers
Positive Attitudes	Decision to Study Science in University	Friends / Peers
Subject Choices	Completion of Undergraduate Degree	Family Support
Personal Traits	Completion of Post Graduate Degree/ Career	Personal Traits

Figure 7.1 *Final Conclusion for the Three Objectives.*

7.2 Limitations

Restriction of the suitability of the participants for the study

From the 16 initial candidates there were some who would have been more suitable for this longitudinal study. It was therefore disappointing that some students, who as Year 11 and 12 students were very eager to take part in the study and signed all the required consent forms, later had a change of mind, as was acceptable based on the agreed ethics for the research (see Appendices A and J).

Loss of contact

Case studies 9, 14 and 15 lost contact with the researcher and thus were eliminated from the study. Some attempts were made to contact them by phone and email, but it seemed that these contact possibilities had changed from early days and messages were not returned. Thus, the early information was now of no use for the study. This frustrating loss of contact was indeed a limitation of the study because these students were all studying for science and science-related degrees and would have added useful information to this study whether they continued with science or not (see Figure 3.1).

Changed from Science degrees

Case Studies 10, 11 and 13 did not go on to complete Science degrees but changed after the first year. They were all promising science students when they were in school. Their early attitudes are still relevant as part of the initial cohort. (see Figure 3.1).

Unwillingness to impart information

Two participants of the final cohort were unwilling to disclose their university results and were included in this study anyway because they gave all other details required. However, this can be considered a limitation as a comparison of the graphical analysis of the university credits and distinctions was eliminated by the researcher, and only the school results were displayed.

Unwillingness to continue as a participant

Two participants were reluctant to continue with the study and in accordance with the agreed ethics, the researcher respected their wishes and withdrew them formally from the study (see Figure 3.1).

Later addition

One participant replaced the original Case Study 6 who dropped most of her science units in university. This participant was added to the study in 2013 and was from a different school. She is the only candidate who came from a government school in Sydney.

Changes to the relationship over time between the researcher and the participants

Seven of the eight final participants had been in the same school though they did the HSC during different years. They were taught by the same science teachers including the researcher. They were fresh young enthusiastic students who had every desire to go on to university and study science. They filled in their consent forms and assured the researcher of their interest in taking part in this study. They in turn were reassured that they could opt out of the study at any time if they wished. As the years passed some of this enthusiasm waned for a few of the participants, and it seemed that they were not so eager to impart information. The natural maturing of these students into young adults was respected and so the researcher let a lot of time pass before asking for details. When some students declined to give details, the researcher allowed them to opt out of the study and looked for other participants to replace the original ones. Some students were overjoyed when contacted by the researcher after a period because they had been so successful in their studies and had even gone on to take up a career related to science. The researcher was able to obtain information from these happy and successful students quite easily. Others were somewhat guarded and restricted in their responses to questions asked and thus the researcher, in accordance with the agreed ethics, did not push them any further to obtain any more information. The personal traits of each candidate were becoming more obvious, and diplomacy and professionalism were required to obtain information, without offending anyone or raising any ethical concerns.

Time Constraints

The researcher had designed a questionnaire for the mothers of the participants to complete. This led to a huge delay in obtaining this information because the mothers were very busy and probably did not view the questionnaire with the same importance as did the researcher. The participants sent this questionnaire to the mothers who were then going to return the questionnaire to their daughters who would then return the

questionnaire to the researcher. This led to a lot of time delays because the researcher did not want to constantly remind the mothers about her request to answer the questionnaire.

Changes in the Social and Political Environment over the years

Australia and the world have changed socially and politically from 2007 to the present time. The students who started university in 2006-2008 had grown up without the digital revolution of Facebook, iPhones, iPads, Instagram, Twitter accounts or other similar methods of communication. Communication has been revolutionised in these last few years and the excess of information about anyone or everyone has become a time-wasting process about which many students of more recent times complain. While the feeling that digital connections were stronger, and information was relayed faster and more broadly, this was not an advantage in this present longitudinal study because the researcher as well as some of the students stuck to rather old-fashioned methods of email and more recently text messages to relay and obtain information. The students' busy academic lives probably contributed to time lapses between the completion and delivery of questionnaire responses.

The political changes in the Australian Government saw a series of different Prime Ministers take up the role of governing the country (Kevin Rudd, 2007, Julia Gillard, 2010, Kevin Rudd, 2013, Tony Abbot, 2013, and Malcolm Turnbull 2015). The government stances on various educational plans such as promises of a National Curriculum and an Education Revolution (Reid, 2009) caused teachers and school administrators to discuss these issues amongst themselves and sometimes these discussions may have been negative. The teachers discussed these future changes with the participants who realised that these predicted changes within the school curriculum would not affect them directly. Nevertheless, they were concerned about changes which they might face in university. It is not surprising that all the participants did not score the scale item "Government" high in Questionnaire PAU 2. (see Table 5.1).

Changes in the Professional and Personal life of the researcher during the longitudinal study

The researcher concluded work in the independent school where she had been working from 1992- 2013 and therefore lost direct contact with seven of the eight participants who had studied in the same school - and most of whom lived within a suburb or so

away. However, she maintained some contact by phone and email. The researcher transferred to another school closer to her home which was under the same school governing board. She also had to transfer her children to different schools and hence this period of change within her life also resulted in minimal research activity for most of 2013 and 2014. Thus, as expected in most human situations changes in her own life did cause some limitations to the progress of this study.

Collection of Data in Retrospect

For most of the participants the data especially the data related to the school certificate and HSC results were collected immediately after they students sat for the examinations. These data were given to the researcher by the school's director of studies, with the permission of the school principal and with the permission from Curtin University for research at minimal ethics risk (see Appendix A). However, for students who were added to the research study as late as 2013, these data had to be researched from school records and hence took up some time. Some of the participants completed the TOSRA after they had finished school.

The interviews through questionnaires were designed for the student while they were in university. Here again some of the questionnaires had to be emailed after the students had completed their degree, hence they were answering questions in retrospect. This lack of original answers could be a limitation of this study. A more mature approach to questions would vary slightly from an impulsive but truer and more natural response.

Short Questionnaires

While collecting and analysing the data from the questionnaire PAU 2, the researcher realised that the questions though direct and clear were few. She would have like to have asked the same question in various ways using slightly different vocabulary. Thus, the participants' answers to some of the questions would be more reliable. For example, there were only three questions for each scale item in this questionnaire and it would have been far better to have had about nine or ten questions for each scale. This the researcher realised later and considered the short questionnaire to be a limitation towards obtaining very accurate data from the participants. However, this short questionnaire may well have been a benefit in gaining responses from the participants.

Similar Participant Background

The participants were all from the same school, and therefore had been taught by the same teachers. Their parents had similar values both moral and religious. All the participants were well looked after and supported by their parents, teachers and friends. The focus of their parents was on their children's education, and this was true for all eight case studies. The cross section of families from which this information has been obtained would be considered a small range. Therefore, the lack of variety among the participants could be a limitation but in fact points directly to the relationship between the school, parents and teachers of this school as being an influential factor for the students' academic success. More details of this relationship will be discussed under the final conclusions.

Limited Control

Just as parents have limited control on their children once they leave home, in the same way the researcher had limited control over the details of the progress of the participants once they left school to go to university. Much patience and time was reserved for the completion of the degrees many of which were in different years and in different universities. The electronic connection was of vital importance and played a strong role in keeping up with the students' progress. However, this was erratic and frustrating at times and was limiting, compared to face-to-face interviews. FaceTime and Skyping would have sufficed, yet the researcher did not use these methods fearing that they may be invasive to the personal lives of the participants.

Shifting Sands

As sand shifts and alters the landscape over time, so did some of the original criteria for this study get adjusted over the period allocated to the research. The influence of the friends in university seemed quite strong and this was evident from the participants' responses to Questionnaire PAU 2. This observation encouraged the researcher to write another questionnaire to obtain more information about how the participants' friends had influenced them. Also, the influence of the family started to become clear as data were examined, thus propelling the researcher to refine and redefine questions for the parent questionnaire (M 4) to obtain further information about the mothers' influence on their daughters' study patterns.

Literature Update

This longitudinal study involved collecting and researching literature at the start and while the participants were completing their degrees. The literature which was read and used for this study at the beginning of the research became outdated. Various edits had to be made to remove the outdated literature and introduce new and relevant literature. While the literature chosen is relevant, a lot of research previously collected was eliminated.

Removal of the School Certificate Examination

The School Certificate Examination which was organised by the Board of Studies New South Wales (BOSTES), which is now called New South Wales Standards Authority (NESA), was ended in 2013 for various reasons, one of them being financial. It was also part of the plan of the government that most students would go on to do Year 11 and 12 and students would thus stay in school for a longer time and that school could run their own internal Year 10 examinations. So even though this examination was used by the researcher as a comparison for the participants, it is now obsolete. Therefore, future research will not be able to compare the student results of the School Certificate examination with the Higher School Certificate. This makes the study unique.

7.3 Recommendations.

In the light of the findings which are shown below some recommendations may be made for science education in school and universities in Australia and especially New South Wales. As these conclusions have been drawn from a focussed study over a reasonable period 2007-2016, these recommendations if followed in government, Catholic or private schools would benefit female students who would like to study science and take up science or science-related careers.

To conclude the factors which have contributed to the students' perseverance in science education are Personal Traits, Friends, Family, Careers and Teachers. This chapter strives to make some recommendations for schools and universities regarding teacher influence which though determined as fourth by participants (see Figure 5.22) and third by mothers of the participants (see Figure 6.11) has still been consistent and significant.

Science Teacher Training

From the early attitude test TOSRA (see Table 4.5) and from early discussion with all 16 participants it was obvious that students enjoyed their science lessons. As has been demonstrated in the literature, teacher quality and enthusiasm can influence students' performance (Chapter 2, Section 2.7 Secondary Teacher Influence, Lyons & Quinn, 2011). A high standard of science teaching in Australia will benefit all students in the country. At the end of this study the participants had good science teachers and rated their influence on their choice of subjects and success as important (see Table 5.1).

Classroom Climate and Teaching Strategies

The third part of the first research question asked about the classroom climate and teaching strategies used in the school to develop in the participants a love for science (see Chapter 4. Section 4.3: Research Question 1c). The varied and interesting activities as well as the excursions, science days, and teaching strategies used in the participants' school could be recommended to other schools. The activities included group work and problem-solving methods, first and second-hand investigations, visits to universities for practical work, analysis of documentaries, and documenting work through photography.

School Science Departments

The effectiveness of a Science department will depend largely on the quality of the teaching, and the use of teaching aids both electronic and other. The leadership displayed by the school leaders and the level of communication between staff members is important. The practical component of the course and the laboratory procedures, openness to innovations and improvement for all members of the teaching staff are necessary. The New South Wales Standards Authority (NESA) have commenced from 2018, a new accreditation process for every teacher in the state. It has now become necessary for all staff members to take part in update and keep records of all professional development courses. These government recommendations for all teachers including science teachers complements the recommendations of this study.

(https://education.nsw.gov.au/teaching-and-learning/professional-learning/teacher-quality-and-accreditation).

Career Direction

Even though the effect of scientists on the participants of this study was found to be inconclusive (see Questionnaire PAU 2 Table 5.1), it is recommended that schools make use of visiting professionals, some of whom may be scientists, others could be science reporters or professionals connected with science through the media, such as Professor Brian Cox who visited Sydney in 2017 (see Chapter 2 Section 2.8). Professionals such as doctors, research assistants, biomedical engineers, and marine biologists, could give talks to students and relate their careers back to science education thus serving as role models for students. This will allow students to see that science education does lead to numerous and varied careers. The eight participants had been to various career exhibitions and guest speakers were invited to speak in the school on various occasions.

Friends in University

Students in university are good role models for students who are in their final years at school. The participant responses to Questionnaire PAU 2 showed that their friends at university had a very strong influence on their academic progress (see Table 6.1). This was reinforced by responses to Questionnaire PAU 3 (see Chapter 6, Section 6.1). It is a recommendation therefore that all schools encourage the old students' associations and work on creating a program which allows ex-students to recount their university experiences, give helpful advice to school leavers about their experiences and even recount their mistakes. In science education, it is important that future science students learn first-hand about the university procedures and scholarships which may be available for them to apply. Three of the eight participants came back to their school during the years 2011 – 2013 to talk about their university experiences and their feedback to teachers, parents and students and this was beneficial
to all concerned. The participants' school has constantly adjusted its career program to synchronise with the changes taking place in the career market and consequently the university courses linked with these changes

Science Scholarships

Students should be encouraged to take part in competitions such as Olympiads, ICAS and Big Science as all the participants, including the original 16 participants had completed at least one, of the above three competitions. Anita who went on to achieve

a distinguished university award, had started her successful career by obtaining distinctions and credits in these earlier competitions, which had been offered to her in school, thus setting the stage for her future success. The same can be said of Jennifer, and Xanthe. These science competitions, and scholarships should be available to every deserving female student in the state irrespective of which type of school they attend. As these competitions are national it is possible to separate deserving students by merit.

Parental Involvement in Schools and in their Children.

It is gradually emerging from the analysis for questionnaires from this study that the parental influence, especially that of the mother on the student, has played a role in helping the student to achieve her goals. These students, except for one, went to a school where the parents were very involved in school activities. It could be added that the study has proved that parents play an extremely functional role in ensuring that the students have confidence and belief in themselves, thus developing the personal traits necessary for persevering with any branch of study, in this case science. The school administration was closely linked with the parent body of the school in which seven of the participants studied. Parents were invited to the school every term to meet the tutor of each participant who acted as the coordinator between the student, teachers and parents (see Chapter 4 Section 4.3 Tutorial System). As each student had been assigned a tutor for her entire school life, there was continuity in identifying and working on the overall development of the students' character as well as refinement in the progress of good habits and academic progress. This unique relationship between the school and parents has proved beneficial to the participants- their teachers knew not just them well but were also well connected with their parents. Their parents had the freedom to address any issue be it academic or general to their tutor who would follow through. Communication on either side was direct, personal and continuous. Yet it could be argued that for personal traits, some are inherited but many are developed, and this happens when the person has been placed in the most suitable environment surrounded by caring and nurturing parents, teachers and tutor. Hence even though these students had a unique experience due to the school in which they studied, other schools could benefit from a similar philosophy and thus get parents more involved in their children's education. Charlotte, who did not go to this school, was also very successful. Her personal traits are also linked to her family cultural

background- her parents were very closely connected with her and totally involved in her education and career decisions (see Figure 6.7). They made appointments and met teachers to help her progress, even though it was not part of her school system.

7.4 Conclusion

Comparison of the eight case studies reveals that there are more similarities between the participants than differences. The differences did not in any way influence the participant' academic journeys and success in completing their degrees. The similarities between the participants, points to individual and strong personalities, confidence and diligence, consistent support from family members irrespective of family size, a good education from a same sex school and teacher guidance during secondary school years.

Perseverance is a virtue which can develop with the correct environment and personal disposition. It is a virtue which all human beings should strive to achieve to be successful. Academic goals can be set from an early age, but progress to achieve them involves hard work and strong support from parents, teachers and friends. Female students, when placed in the environment which respects them as individuals, when encouraged by parents and teachers to study science, when inspired by science educators to take up science careers, when able to learn from successful female scientists of the past and present, will find it easier to achieve their goals. There is no straight forward formula for their success - it lies in the combinations of all the factors discussed in this study. It is therefore fitting that the concluding words for this longitudinal study of female science students should be made by one of the most famous female scientists whose perseverance and diligence resulted in her scientific success.

"*Life is not easy for any of us. But what of that? We must have perseverance and above all confidence in ourselves. We must believe that we are gifted for something and that this thing must be attained" Marie Curie (Streznewski, 1999, p.129).*

REFERENCES

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education*, *82*(4), 417–436.

Albright, R. N. (2014). *The double helix structure of DNA: James Watson, Francis Crick, Maurice Wilkins, and Rosalind Franklin. (Revolutionary Discoveries of Scientific Pioneers).* New York: Rosen Publishing Group.

Allegrini A. (2015) Gender, STEM Studies and Educational Choices. Insights from Feminist Perspectives. In E. K. Henriksen, J. Dillon J., & J. Ryder (Eds.), *Understanding student participation and choice in science and technology education* (pp.43–49). Dordrecht: Springer.

Appleton, K. (1995). Student teachers' confidence to teach science: Is more science knowledge necessary to improve self-confidence? *International Journal of Science Education*, *17*(3), 357–369.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). ``Balancing acts": Elementary school girls' negotiations of femininity, achievement, and science. *Science Education*, *96*, 967–989.

Aris, S. (2017). Indian tigers: What high school selection by parents pursing academic performance reveals about class, culture and migration. *Journal of Ethnic and Migration Studies*, *43*(14), 2440–2455.

Attenborough, D. (2002) Life on air: Memoirs of a broadcaster. London: BBC Books

Baker, D. R. (2016). Letting girls speak out about science. In D. R. Baker (Ed.) *Understanding girls: Qualitative and quantitative research* (pp. 89–125). Rotterdam. Sense Publishers.

Barnett, R. C., & Sabattini, L. (2009). A short history of women in science: From stone walls to invisible walls. In C. H. Sommers (Ed.). *The science on women and science* (pp.1–10). Washington, DC: American Enterprise Institute

Barry, A. E. (2005). How attrition impacts the internal and external validity of longitudinal research. *The Journal of School Health*, *75*(7), 267–70.

Berger, N., & Archer, J. (2016). School socio-economic status and student socio-academic achievement goals in upper secondary contexts. *Social Psychology of Education*, *19*(1), 175–194.

Bertin, C. (1987). *Marie Bonaparte, a life*. New Haven: Yale University Press.

Bleeker, M. M., & Jacobs, J. E. (2004). Achievement in math and science: Do mothers' beliefs matter 12 years later? *Journal of Educational Psychology*, *96*(1), 97–108.

Bodanis, D. (2009). *Passionate Minds: Emilie du Châtelet, Voltaire, and the great love affair of the enlightenment*. New York: Broadway Books.

Bouchey, H. A., Shoulberg, E. K., Jodl, K. M., & Eccles, J. S. (2010). Longitudinal links between older sibling features and younger siblings' academic adjustment during early adolescence. *Journal of Educational Psychology*, *102*(1), 197–211.

Boyd, E., & Letherby, G. (Eds.). (2014). *Stay-at-home mothers: Dialogues and debates*. Bradford, ON: Demeter Press. Retrieved from http://www.jstor.org/stable/j.ctt1rrd80z

Brody, G. (2004). Siblings' direct and indirect contributions to child development. *Current Directions in Psychological Science*, *13*(3), 124–126.

Burgess, J., & Unwin, D. (1984). Exploring the living planet with David Attenborough. *Journal of Geography in Higher Education*, 8(2), 93–113.

Campbell, J. R., & Wu, W. T. (1996). Development of exceptional academic talent: International research studies. International *Journal of Educational Research*, 25(6), 479–484.

Campbell, T. Stanley J. C. (1966) *Experimental and quasi-experimental designs.* Chicago, Ill: Rand McNally.

Cardona, B., Watkins, M., & Noble, G. (2009). *Parents, diversity and cultures of home and school*. Penrith, NSW: University of Western Sydney. Retrieved from

http://www.uws.edu.au/__data/assets/pdf_file/0010/475768/Parents_Diversity_Report.pdf

Casadevall, A., & Handelsman, J. (2014). The presence of female conveners correlates with a higher proportion of female speakers at scientific symposia. *MBio*, *5*(1) e00846-13 https://med.stanford.edu/content/dam/sm/wim/resources/research/Casadevall-2014-Female-Speakers-Symposia.pdf

Charmaz, K. (2000). Grounded theory: Objectivist and constructionist methods. In N. K. Denzin, & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed.) (pp 509–536). Thousand Oaks, CA: Sage Publications.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative research.* London: Sage Publications Ltd.

Charmaz, K. & Henwood, K. (2008). Grounded theory. In C. Willig, C. & W. Stainton-Rogers (Eds.), *The SAGE handbook of qualitative research in psychology* (pp. 240–260). London: Sage.

Charmaz, K. (2011). Grounded theory methods in social justice research. In N. K. Denzin, & Y. S Lincoln (Eds.), *The SAGE handbook of qualitative research* (pp. 359–380). Thousand Oaks, CA: SAGE.

Chiu, M. H., & Wang, N. Y. (2011). Marie Curie and science education. In Chiu, M. H., Gilmer, P. J., & Treagust, D. F. (Eds.), *Celebrating the 100th anniversary of Madame Marie Sklodowska Curie's Nobel Prize in Chemistry* (pp. 9–39). Rotterdam: Sense Publishers.

Clancy, K. B., Lee, K. M., Rodgers, E. M., & Richey, C. (2017). Double jeopardy in astronomy and planetary science: Women of color face greater risks of gendered and racial harassment. *Journal of Geophysical Research: Planets*, *122*(7), 1610-1623.

Clark, J., Zuccala, E., & Horton, R. (2017). Women in science, medicine, and global health: Call for papers. *The Lancet*, *390*(10111), 2423–2424.

Clarke, A. E. (2005) *Situational analysis: Grounded theory after the postmodern turn.* Thousand Oaks, CA: Sage Publications.

Cole, J. (2011) *A research review: The importance of families and the home environment* [originally written by Bonci, A., (2008), revised by Mottram, E. & McCoy, E. (2010)]. London: National Literacy Trust.

Corbin, J., Strauss, A., & Strauss, A. L. (2014). *Basics of qualitative research.* Thousand Oaks, CA: Sage Publications

Corlu, M. S., Capraro, R. M., & Capraro, M. M. (2014). Introducing STEM education: Implications for educating our teachers in the age of innovation. *Education and Science*, *39*(171), 74–85.

Cox, B. & Cohen, A. (2011) *Wonders of the universe*. London: Harper Collins Publisher.

Cridge, B. J., & Cridge, A. G. (2015). Evaluating How Universities Engage School Students with Science: A Model Based on the Analysis of the Literature. *Australian Universities' Review*, *57*(1), 34–44.

Crowley, K., Callanan, M. A., Tenenbaum, H. R., & Allen, E. (2001). Parents explain more often to boys than to girls during shared scientific thinking. *Psychological Science*, *12*(3), 258–261.

Ceci, S. J., & Williams, W. M. (2007). *Why aren't more women in science? Top researchers debate the evidence*. Washington, DC: American Psychological Association.

Davis-Kean, P. E. (2005). The influence of parent education and family income on child achievement: the indirect role of parental expectations and the home environment. *Journal of Family Psychology*, *19*(2), 294–304.

Dey, I. (1999). *Grounding Grounded Theory: Guidelines for qualitative inquiry*. London: Academic Press.

Denzin, N.K., Lincoln, Y.S. (1998). *Collecting and interpreting qualitative materials.* Thousand Oaks, CA: Sage Publications.

Dhatt, R., Kickbusch, I., & Thompson, K. (2017). Act now: A call to action for gender equality in global health. *The Lancet*, 389(10069), 602.

Dingwall, R., & Aldridge, M. (2006). Television wildlife programming as a source of popular scientific information: A case study of evolution. Public Understanding of Science, 15(2). 131–152.

Donat, S. M. (2015). *The relationship among parental style, involvement, influence and undergraduate student success* (Unpublished Doctoral dissertation, Indiana University of Pennsylvania, Indiana).

Dzielska, M. (1995). *Hypatia of Alexandria.* Boston MA: Harvard University Press.

Donnelly, K. (2015). *Australia's great divide: Who values education?* https://www.theage.com.au/education/australias-great-divide-who-values-education-20150204-1369ga.html

Duffield, J. (2009). *A Cry for Help*. American World Press. *https://www.amazon.com/Cry-Help-John-Duffield/dp/0578028239*

Dunn, J. (1983). Sibling relationships in early childhood. Child Development, 54(4), 787–811.

Eisenhardt, K. M. (1989). Building theories from case study research. *The Academy of Management Review*, *14*(4), 532–550.

Emerson, L., Fear, J., Fox, S., & Sanders, E. (2012). *Parental engagement in learning and schooling: Lessons from research. A report by the Australian Research Alliance for Children and Youth (ARACY) for the Family–School and Community Partnerships Bureau*. Canberra: The Family-School and Community Partnerships Bureau.

Fiala, K. (2006). *Alterquest: The alternative quest for answers.* Morrisville. NC: Lulu Press Inc.(http://www.lulu.com)

Floro, M., & Wolf, J. M. (1990). *The Economic and Social Impacts of Girls' Primary Education in Developing Countries.* Washington, DC: Creative Associates, Inc., Office of Education and Women in Development, Agency for International

Development (ERIC Document Reproduction Services, ED362453). https://files.eric.ed.gov/fulltext/ED362453.pdf

Fraser, B. J. (1981). *Test of science-related attitudes*. Melbourne: The Australian Council for Educational Research.

Fraser, B. J. (1986). *Classroom environment*. London: Croom.

Fraser, B.J. (1994). Research on classroom and school climate. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 493–541). New York: Macmillan.

Glaser, B. & Strauss, A. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago: Aldine

Glaser, B. G. (1998). *Doing grounded theory: Issues and discussions*. Mill Valley CA: Sociology Press.

Glaser, B. G. (1992). *Basics of grounded theory analysis: Emergence vs forcing*. Mill Valley, Calif.: Sociology Press.

Glaser, B. G., & Strauss, A. L. (2017). *Discovery of grounded theory: Strategies for qualitative research.* New York: Routledge.

Hackling, M., Peers, S., & Prain, V. (2007). Primary Connections: Reforming science teaching in Australian primary schools. *Teaching Science*, *53*(3), 12.

Hadfield, C. (2013). *An astronaut's guide to life on Earth*. Toronto: Random House Canada.

Hall, M. B. (1994). *The scientific renaissance 1450–1630*. New York: Dover Publications.

Harding, S. G. (2016). *Whose science? Whose knowledge?:Thinking from womens's lives.* New York: Cornell University Press.

Harlen, W., & Holroyd, C. (1997). Primary teachers' understanding of concepts of science: Impact on confidence and teaching. *International journal of science education*, *19*(1), 93–105.

Hauser, R. M., & Wong, R. S. (1989). Sibling resemblance and intersibling effects in educational attainment. *Sociology of Education*, *62* (3), 149–171.

Hernandez, P. R., Bloodhart, B., Barnes, R. T., Adams, A. S., Clinton, S. M., Pollack, I., ... & Fischer, E. V. (2017). Promoting professional identity, motivation, and persistence: Benefits of an informal mentoring program for female undergraduate students. *PloS ONE*, *12*(11), e0187531.

Hill, C., Corbett, C., & St Rose, A. (2010). *Why so few? Women in science, technology, engineering, and mathematics*. Washington, DC: American Association of University Women (AAUW).

Hunter, B., & Schwab, R. G. (1998). *The determinants of Indigenous educational outcomes*. Centre for Aboriginal Economic Policy Research (CAEPR) Discussion Paper No. 160, CAEPR, Australian National University. Canberra.

Hyde, J. S. (2007). New directions in the study of gender similarities and differences. *Current Directions in Psychological Science*, *16*(5), 259–263.

Johnson, S. (1825) *The works of Samuel Johnson*. Philadelphia: H. C. Carey & I Lea.

Kaur, B. (2010). Towards excellence in mathematics education–Singapore's experience. *Procedia-Social and Behavioural Sciences*, *8*, 28-34.

Kuehn, T. (1996). Understanding gender inequality in Renaissance Florence: Personhood and gifts of maternal inheritance by women. *Journal of Women's History*, *8*(2), 58–80.

Laven, M. (2003). *Virgins of Venice: Broken vows and cloistered lives in the Renaissance convent*. New York: Penguin Publications

Larivière, V., Ni, C., Gingras, Y., Cronin, B., & Sugimoto, C. R. (2013). Bibliometrics: Global gender disparities in science. *Nature News*, *504*(7479), 211.

Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching*, *36*(8), 916–929.

Lyons, T., Quinn, F., Rizk, N., Anderson, N., Hubber, P., Kenny, J., ... & Wilson, S. A. (2012). Starting out in STEM: A study of young men and women in first year science, technology, engineering and mathematics courses. University of New England, Armidale, NSW.

Lyons, T., & Quinn, F. (2010). *Choosing Science: Understanding the declines in senior high school science enrolments.* National Centre of Science, ICT and Mathematics Education for Rural and Regional Australia (SiMERR Australia), University of New England, Armidale, NSW.

Maher, M. A., Ford, M. E., & Thompson, C. M. (2004). Degree progress of women doctoral students: Factors that constrain, facilitate, and differentiate. *The Review of Higher Education, 27*(3), 385–408.

Manser, M. H. (2001) *The Westminster collection of Christian quotations*. Westminster: John Knox Press.

Marginson, S., Tytler, R., Freeman, B., & Roberts, K. (2013). *STEM: Country comparisons - international comparisons of science, technology, engineering and mathematics (STEM) education*. Final report for Australian Council of Learned Academies, Melbourne.

Marshall, B., & Adams, P. C. (2008). Helicobacter pylori: A Nobel pursuit? *Canadian Journal of Gastroenterology, 22*(11), 895–896.

Mason, S. (2002). Galileo's scientific discoveries, cosmological confrontations, and the aftermath. *History of Science, 40*(4), 377–406.

McCabe, J. (2016). Friends with academic benefits. *Contexts, 15*(3), 22–29.

McGinn, K. L., Ruiz Castro, M., & Long Lingo, E. (2015). Mums the word! Cross-national effects of maternal employment and gender inequalities at work and at home. *Harvard Business School Working Paper*, No. 15-094, July.

McHale, S. M., Updegraff, K. A., & Whiteman, S. D. (2012). Sibling Relationships and Influences in Childhood and Adolescence. *Journal of Marriage and the Family, 74*(5), 913–930.

Miles, M.B., Huberman, A.M. (1994). Qualitative data analysis: An expanded sourcebook (2nd ed.), Thousand Oaks, CA: Sage Publications.

Milkman, K. L., Akinola, M., & Chugh, D. (2015). What happens before? A field experiment exploring how pay and representation differentially shape bias on the pathway into organizations. *Journal of Applied Psychology*, *100*(6), 1678.

Misra, J., Lundquist, J. H., & Templer, A. (2012). Gender, work time, and care responsibilities among faculty. *Sociological Forum*, 27(2), 300–323.

Monosson, E. (2008). *Motherhood, the elephant in the laboratory: Women scientists speak out.* New York. Cornell University Press.

Morse, J. M., Stern, P. N., Corbin, J., Bowers, B., Clarke, A. E., & Charmaz, K. (2009). *Developing grounded theory: The second generation*. New York: Routledge.

Morse, J. M. (2016). *Mixed method design: Principles and procedures*. New York: Routledge.

Moss-Racusin, C. A., Dovidio, J. F., Brescoll, V. L., Graham, M. J., & Handelsman, J. (2012). Science faculty's subtle gender biases favor male students. *Proceedings of the National Academy of Sciences*, *109*(41), 16474–16479.

Mullis, R. L., Mullis, A. K., Cornille, T. A., Ritchson, A. D., & Sullender, M. S. (2004). *Early literacy outcomes and parent involvement. Tallahassee*, FL: Florida State University Press.

Oakley, A., (2016). Interviewing women again: Power, time and the gift. *Sociology*, *50*(1), 195-213.

Ono, H. (2004). Are sons and daughters substitutable? Allocation of family resources in contemporary Japan. *Journal of the Japanese and International Economies*, *18*(2), 143–160.

Palmer, D. H. (2002). Factors contributing to attitude exchange amongst preservice elementary teachers. *Science Education*, *86*(1), 122–138.

Pickering, M. (1999). Joy Harvey. “Almost a Man of Genius”: Clémence Royer, Feminism, and nineteenth-century science. (Lives of women in science.) New Brunswick, NJ: Rutgers University Press. *The American Historical Review, 104*(1), 251–252.

Pickover, C. (2008). Archimedes to Hawking: laws of science and the great minds behind them. Oxford: Oxford University Press.

Reddy, D. (2015). Impact of Women in Mathematics – Review with Special Reference to Lilavati. *i-manager’s Journal on Mathematics*, *4*(1), 46–54. https://doi.org/10.26634/jmat.4.1.3239

Rennie, L. J., Goodrum, D., & Hackling, M. (2001). Science teaching and learning in Australian schools: Results of a national study. *Research in Science Education*, *31*(4), 455–498.

Reid, A. (2009). *Is this a revolution? A critical analysis of the Rudd government's national education agenda*. Australian Curriculum Studies Association, Deakin West, ACT. http://acsa.edu.au/pages/images/ACSA%20Boomer%20address.pdf

Ribu, K. (2007) Retaining Women in Engineering Education Through Network Groups and Mentoring. 9th International Conference on Engineering Education. R4E-15. July 2006. San Juan PR, USA.

https://www.researchgate.net/publication/228944121

Rife, P., & Grove, J. W. (2001). Lise Meitner & the dawn of the nuclear age. *Queen's Quarterly*, *108*(1), 84

Roksa, J., & Potter, D. (2011). Parenting and academic achievement: Intergenerational transmission of educational advantage. *Sociology of Education*, *84*(4), 299–321.

Rossiter, M. W. (1982). Women scientists in America: Struggles and strategies to 1940. Baltimore: John Hopkins University Press.

Rothman, S. (2003, April). *The changing influence of socioeconomic status on student achievement: Recent evidence from Australia*. Paper presented at the annual meeting of the American Educational Research Association, Chicago.

Shapiro, J. R., & Williams, A. M. (2012). The role of stereotype threats in undermining girls' and women's performance and interest in STEM fields. *Sex Roles*, *66*(3-4), 175-183.

Silverberg, A. (2006). Women at Harvard. *Newsletter of the Association for Women in Mathematics*, *36*(3), 17–20

Silverman, D. (2014). *Interpreting qualitative data*. Los Angeles: Sage Publications.

Sime, R. L. (1990). Belated recognition: Lise Meitner's role in the discovery of fission. *Journal of Radioanalytical and Nuclear Chemistry*, *142*(1), 13–26.

Sime, R.L. (1996). *Lise Meitner: A life in Physics*. Berkeley: University of California Press.

Simpson, R. D., & Steve Oliver, J. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education*, *74*(1), 1–18.

Sirin, S. R. (2005). Socioeconomic status and academic achievement: A meta-analytic review of research. *Review of Educational Research*, *75*(3), 417–453.

Song, M. P., & Hattie, H. D. (2004). Home-school relationship as they affect the academic success of children. *Education and Urban Society*, *16*(2), 333–347.

Sonnert, G. (2009). Parents who influence their children to become scientists: Effects of gender and parental education. *Social Studies of Science*, *39*(6), 927–941.

Strauss, A., & Corbin, J. M. (1990). Basics of qualitative research: Grounded theory procedures and techniques. Thousand Oaks CA: Sage Publications, Inc.

Steinpreis, R. E., Anders, K. A., & Ritzke, D. (1999). The impact of gender on the review of the curricula vitae of job applicants and tenure candidates: A national empirical study. *Sex Roles*, *41*(7–8), 509–528.

Streznewski, M. K. (1999). *Gifted grownups: The mixed blessing of extraordinary potential*. New York. J Wiley & Sons.

Stone, T. L., & Priceman, M. (2013). *Who says women can't be doctors? The story of Elizabeth Blackwell* (1st ed.). New York: Christy Ottaviano Books/Henry Holt and Co.

Terrall, M. (1995). Emilie du Châtelet and the gendering of science. *History of Science*, *33*(3), 283–310.

Turner, A. (2015). Generation Z: Technology and social interest. *The Journal of Individual Psychology*, *71*(2), 103–113.

Ulrich, L. T. (1999). Harvard's womanless history. *Harvard Magazine*, *102*, 50–59.

Ulrich, L. T. (2004). *Yards and gates: Gender in Harvard and Radcliffe history*. New York: Palgrave Macmillan.

Vázquez-Cupeiro, S., & Elston, M. A. (2006). Gender and academic career trajectories in Spain: From gendered passion to consecration in a Sistema Endogámico? *Employee Relations*, *28*(6), 588–603.

Wang, M., & Degol, J. (2013). Motivational pathways to STEM career choices: Using expectancy-value perspective to understand individual and gender differences in STEM fields. *Developmental Review*, *33*(4) 304–340.

Wang, M. T., & Degol, J. L. (2016). Gender Gap in Science, Technology, Engineering, and Mathematics (STEM): Current Knowledge, Implications for Practice, Policy, and Future Directions. *Educational psychology review*, *29*(1), 119-140.

Watkins, M., Ho, C., & Butler, R. (2017). Asian migration and education cultures in the Anglo-sphere. *Journal of Ethnic and Migration Studies*, *43*(14), 2283–2299.

Wertheim, M. (1996). Pythagoras' trousers. *Math Horizons*, *3*(3), 5–7.

Westfall, R. S. (1983). Never at rest: A biography of Isaac Newton. Cambridge: Cambridge University Press.

White E.L. & Harrison T.G. (2012). UK school students' attitudes towards science and potential science-based careers, *Acta Didactica Napocensia*, *5*(4), 1–10.

Whiteman, S. D., & Christiansen, A. (2008). Processes of sibling influence in adolescence: Individual and family correlates. *Family Relations*, *57*(1), 24–34.

Williams, W. M., & Ceci, S. J. (2012). When Scientists choose motherhood: A single factor goes a long way in explaining the dearth of women in math-intensive fields. How can we address it? *American Scientist*, *100*(2), 138.

Williams, J. C., Phillips, K. W., & Hall, E. (2016). Tools for Change: Boosting the Retention of Women in the Stem Pipeline. *Journal of Research in Gender Studies*, *6*(1), 11.

Willig, C. (2013). *Introducing qualitative research in pyschology* (3rd ed.). Maidenhead, UK: McGraw-Hill Education

Wilson, R., & Mack, J. (2014). Declines in high school mathematics and science participation: evidence of students' and future teachers' disengagement with maths. *Internationa Journal of Innovation in Science and Mathematics Education* (formerly *CAL-laborate International*), 22(7), pp.35–48.

Wolf-Wendel, L. E., & Ward, K. (2006). Academic life and motherhood: Variations by institutional type. *Higher Education*, *52*(3), 487–521.

Wu, M. & Hornsby, D. (2014) Inappropriate use of NAPLAN results (online). *Practically Primary*, *19*(2),16–17.

Yates, S., & Goodrum, D. (1990). How confident are primary school teachers in teaching science? *Research in Science Education*, *20*(1), 300–305.

Yee, D.K. & Eccles, J.S. (1988) Parent perceptions and attributions for children's math achievement. *Sex Roles*, *19*(5) 317–333.

Yin, R. K. (2009) Case study research: Design and methods (4th ed.). (25–66). Thousand Oaks, CA: Sage Publications.

Yin, R.K., (1994). *Case study research: Design and methods*. Thousand Oaks, CA: Sage Publications.

APPENDICES

APPENDIX A

memorandum

Curtin University of Technology

To	Isabel Blades, SMEC
From	Pauline Howat, Coordinator for Human Research Ethics, Science and Maths Education Centre
Subject	Protocol Approval **SMEC-03-10**
Date	19 February 2010
Copy	David Treagust, SMEC Divisional Graduate Studies Officer, Division of Science and Engineering

Office of Research and Development

Human Research Ethics Committee

TELEPHONE 9266 2784
FACSIMILE 9266 3793
EMAIL hrec@curtin.edu.au

Thank you for your "Form C Application for Approval of Research with Minimal Risk (Ethical Requirements)" for the project titled "*PERSEVERANCE IN SCIENCE EDUCATION*". On behalf of the Human Research Ethics Committee I am authorised to inform you that the project is approved.

Approval of this project is for a period of twelve months **9th February 2010** to **8th February 2011**.

If at any time during the twelve months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately. The approval number for your project is **SMEC-03-10**. *Please quote this number in any future correspondence.*

Pauline

PAULINE HOWAT
Coordinator for Human Research Ethics
Science and Maths Education Centre

Please Note: The following standard statement must be included in the information sheet to participants: *This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number SMEC-03-10). If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784.*

APPENDIX B

Participants Number, Thesis Name

Participant Number	Thesis Name
1	Jennifer
2	Angela
3	Anita
4	Rita
5	Megan
6*	Marianne
7	Nikolina
8	Xanthe
9	Mary
10	Jane
11	Elizabeth
12	Maria
13	Annalisa
14	Sonia
15	Elyse
16	Susan
Thesis 6* (was not part of the initial 16)	Charlotte In case study chapters early attitude tests omitted for this participant.

APPENDIX C

Initial Questionnaire TOSRA

Test of Science Related Attitudes Handbook, (Fraser, 1981).

Scale Allocation and Scoring For each Item

Social Implications of Science	**Normality of Scientists**	**Attitude to Scientific Inquiry**	**Adoption of Scientific Attitudes**	**Enjoyment of Science Lessons**	**Leisure Interest in Science**	**Career Interest in Science**
1(+)	2(-)	3(+)	4(+)	5(+)	6(+)	7(-)
8(-)	9(+)	10(-)	11(-)	12(-)	13(-)	14(+)
15(+)	16(-)	17(+)	18(+)	19(+)	20(+)	21(-)
22(-)	23(+)	24(-)	25(-)	26(-)	27(-)	28(+)
29(+)	30(-)	31(+)	32(+)	33(+)	34(+)	35(-)
36(-)	37(+)	38(-)	39(-)	40(-)	41(-)	42(+)
43(+)	44(-)	45(+)	46(+)	47(+)	48(+)	49(-)
50(-)	51(+)	52(-)	53(-)	54(-)	55(-)	56(+)
57(+)	58(-)	59(+)	60(+)	61(+)	62(+)	63(-)
64(-)	65(+)	66(-)	67(-)	68(-)	69(-)	70(+)

For positive items (+), responses SA, A, N, D, SD are scored 5,4,3,2, 1, respectively. For negative items (-), responses SA, A, N, D, SD, are scored 1,2,3,4, 5, respectively. Omitted or invalid responses are scored 3.

TOSRA: (Fraser, l981)

TEST OF SCIENCE-RELATED ATTITUDE

DIRECTIONS

1. This test contains a number of statements about science. You will be asked what you yourself think about these statements. There are no 'right' or 'wrong' answers. Your opinion is what is wanted.
2. All answers should be given on the separate Answer Sheet. Please do not write on this booklet.
3. For each statement, draw a circle around

   SA if you STRONGLY AGREE with the statement;

   A if you AGREE with the statement:

   N if you are NOT SURE;

   D if you DISAGREE with the statement:

   SD if you STRONGLY DISAGREE with the statement.

Practice ltem

It would be interesting to learn about boats.

Suppose then you like this: that you AGREE with this statement, would circle A on your Answer Sheet.

SA (A) N D SD

4. If you change your mind about an answer, cross it out and circle another one.
5. Although some statements in this test are fairly similar to other statements, you are asked to indicate your opinion about all statements.

<u>Statements</u>

1. Money spent on science is well worth spending.

2. Scientists usually like to go to their laboratories when they have a day off.

3. I would prefer to find out why something happens by doing an experiment than by being told.

4. I enjoy reading about things which disagree with my previous ideas.

5. Science lessons are fun.

6. I would like to belong to a science club.

7. I would dislike being a scientist after I leave school.

8. Science is man's worst enemy.

9. Scientists are about as fit and healthy as other people.

10. Doing experiments is not as good as finding out information from teachers.

11. I dislike repeating experiments to check that I get the same results.

12. I dislike science lessons.

13. I get bored when watching science programs on TV at home.

14. When I leave school, I would like to work with people who make discoveries in science.

15. Public money spent on science in the last few years has been used wisely.

l6. Scientists do not have enough time to spend with their families.

l7. I would prefer to do experiment than to read about them.

18. I am curious about the world in which we live.

19. School should have more science lessons each week.

20. I would like to be given a science book or a piece of scientific equipment as a present.

21. I would dislike a job in a science laboratory after I leave school.

22. Scientific discoveries are doing more harm than good.

23. Scientists like sport as much as other people do.

24. I would rather agree with other people than do an experiment to find out for myself.

25. Finding out about new things is unimportant.

26. Science lessons bore me.

27. I dislike reading books about science during my holidays.

28. Working in a science laboratory would be an interesting way to earn a living.

29. The government should spend more money on scientific research.

30. Scientists are less friendly than other people.

31. I would prefer to do my own experiments than find out information from a teacher.

32. I like to listen to people whose opinions are different from mine.

33. Science is one of the most interesting school subjects.

34. I would like to do science experiments at home.

35. A career in science would be dull and boring.

36. Too many laboratories are being built at the expense of the rest of education.

37. Scientists can have a normal family life.

38. I would rather find out about things by asking an expert than by doing an experiment.

39. I find it boring to hear about new ideas.

40. Science lessons are a waste of time.

4l. Talking to friends about science after school would be boring.

42. I would like to teach science when I leave school.

43. Science helps to make life better.

44. Scientists do not care about their working conditions.

45. I would rather solve a problem by doing an experiment than be told the answer.

46. In science experiments, I like to use new methods which I have not used before.

47. I really enjoy going to science lessons.

48. I would enjoy having a job in a science laboratory during my school holidays.

49. A job as a scientist would be boring.

50. This country is spending too much money on science.

5l. Scientists are just as interested in art and music as other people are.

52. It is better to ask the teacher the answer than to find it out by doing experiments.

53. I am unwilling to change my ideas when evidence shows that the ideas are poor.

54. The material covered in science lessons is uninteresting.

55. Listening to talk about science on the radio would be boring.

56. A job as a scientist would be interesting.

57. Science can help to make the world a better place in the future.

58. Few scientists are happily married.

59. I would prefer to do an experiment on a topic than to read about it in science magazines.

60. ln science experiments I report unexpected results as well as expected ones

60. Doing experiments is not as good as finding out information from teachers

62. I would enjoy visiting a science museum at the weekend.

63. I would dislike becoming a scientist because it needs too much education

64. Money used on scientific projects is wasted.

65. If you met a scientist he would probably look like anyone else you might meet.

66. It is better to be told scientific facts than to find them out from experiments.

67. I dislike listening to other people's opinions.

68. I would enjoy school if there were no science lessons.

69. I dislike reading newspaper articles about science.

70. I would like to be a scientist when I leave school

APPENDIX D

MEMO Questionnaire PAU 1: General Feedback about the Journey

1. *What are the factors which caused you to take up this Science Course?*
   - Through my schooling career I always enjoyed science-based subjects particularly biology in relation to how certain body systems work, anatomy and biochemistry. Therefore, I knew when I finished school I wanted to work in a field of science that involved the science of the human body in some way.
   - Both my parents work/worked within the health field and I was constantly fascinated with the stories about work they told at home while growing up.
   - I knew growing up that I did not want to go into a career which did not involve working with people in some way. I knew that I wanted to work face to face with a range of people and personalities with the goal of 'helping them' become better/achieve a goal in some way.
   - I also knew that I would need to go into a career which we be challenging, offer variety and not follow a monotonous work schedule.
   - When looking at university courses I knew that I didn't want to enter a long course, nothing more than 5 years, because I was eager to get out into the workforce.

     A combination of these factors all led me to looking into the courses of nursing, physiotherapy and occupational therapy (OT). Ultimately, I chose OT as it held a combination of biology, anatomy, psychology, creativity and was centred on helping others achieve their goals.
2. *What difficulties, if any, did you experience while doing this course?*
   - The placements found hard as some were rural for periods of time (e.g. Dubbo-8 weeks) and although the experiences I gained on them was fantastic they were not as structured as I would've liked them to be. The faculty who organised placements were also very disorganised and not helpful at all!
   - The first year of the course I found very repetitive with no real skills taught that could be transferrable into the field. However, in year 2 I realised how the first-year course provided a foundation of principles which were needed to be innately understood to build the skills upon for the remainder of my career.
3. *What strategies did you use to overcome these difficulties?*
   - Support from my family and friends while I was completing my long placements away from home. I also went into the placements with the goal of keeping an open mind and making new friends in the placements, so I could

create a sort of support system while I was away from home. My religious beliefs also helped me 'stick it out' during stressful/tough times.

- I spoke to other OT students in the years ahead of me to ask if the course continued in the same manner and rate that it did in year 1. Once I was told it wouldn't it made sticking out year one more manageable with the knowledge it would all be worth it in the next 3 yrs of the course.

4. *Did family support play a role in motivating you to complete the course?*
   - Absolutely. My family supported me throughout my whole schooling career, particularly when it came to exam time. They made it clear that they would be happy with whatever I chose to do and reminded me why I chose the course when I had doubts during stressful periods. They were always willing to hear my rants about my days during placement which allowed me an opportunity to debrief which I found very therapeutic. They also were willing to help me financially which was a great load off my shoulders, as lab supplies, and medical textbooks are not cheap!
5. *Can you identify any reasons why you may have not experienced any difficulties while doing this course?*
   - I was confident that I wanted to work in health when I started.
   - I chose my course after long consideration and research to be sure that it was what I wanted.
   - I made close friends with people in my course during my first week of uni and we all supported each other through the rest of our schooling and continue to do so in our graduate years working full time.
   - I found a lot of the basic core principles of OT seemed like 'common sense' to me whereas to others it does not. I felt I just clicked with the main goal of the profession right from the beginning.
6. *Did you take part in extra –curricular activities while doing this course? If so name these activities.*
   - No so much. Mainly due to my work schedule, socialising with friends and having no interest in playing sports. I did play social netball once a week at uni for the first 2 years.
7. *Did you work while doing this course? Give details*
   - Yes. During my first year of the course I worked as a sales assistant at Bakers Delight. I completed 8hr shifts on the weekends and 3-5hour shifts on the days I was not at university.
   - In my second year to my graduation I held two casual jobs which I enjoyed immensely. I found the skills gained from such were transferrable to my OT role. I worked as a residential carer at Inala (assisting with caring for adults in

the group homes with their basic activities of daily living, transport for work and extra-curricular activities), for approximately 10hours a week.

- I worked on the weekends at The Hills Private Hospital as an Allied Health Assistant. I was offered this role after completing a 2-week placement at the hospital during my 2nd yr of study. Within this role I worked closely beside OT's and physiotherapists in carrying out their intervention plans with patients. I now work here full time as an OT.

8. *Did you travel overseas while doing this course? Give the duration of travel.*
   - Yes, a couple of times during the long summer breaks. I went on a cruise to the Pacific Islands (2 weeks) and off to tour Europe (6 weeks).

APPENDIX E

Participant at University-2 Questionnaire - Attitudes, Personal Traits, Influential Factors

No	Statement	SD	D	U	A	SA
1	I have been influenced by my school science teachers to take up a Science subject for the HSC					
2	I have been influenced by my teachers and career advisors to take up a science/ science related degree					
3	I have had discussions with my parents about my choice of Science subjects for the HSC					
4	My brothers and sisters did influence my choice of subjects for the HSC and for University					
5	My tutors/ mentors at university played an active role in helping me to complete the degree I had chosen.					
6	I was influenced by the role played by the Australian Government in promoting science education					
7	I was encouraged to complete the degree with the hope of a successful science related career.					
8	I had friends in university who encouraged and helped me to persevere even when it was difficult					
9	The leading scientist/ scientists in the country/ overseas served as my role models					
10	I was influenced by the social environment and job market during the period of my study years to take up and complete the course					
11	I was influenced and motivated by the life of a scientist, from the past, to take up science in school and university					
12	My mother's managerial skills at home/ at work outside the home encouraged me to better myself at my studies using the opportunities available at that time.					
13	I feel that a science degree is far better for the job market than a non- science degree					
14	I feel that male students and teachers respect me more because I have studied science					
15	My character and personal traits played a role in helping me to complete my degree					

16	I worked very hard and gave up free time to work in the library focusing on assignments and examinations.					
17	I felt that I had the ability to complete the degree successfully because I had a positive attitude towards science education, one I had developed in school.					
18	I feel that there is a direct link between the jobs available for science graduates and the government support for science in schools and universities					
19	I worked with my friends as a team studying together in the library, sharing resources and experiences					
20	I often read about scientists and recent science innovations in science magazines and journals.					
21	Science research will benefit further if the Australian Government makes it a priority.					

APPENDIX E

Participant at University Questionnaire 4 - Attitudes, Personal Traits, Influential Factors

Classification of Items

Teacher /Mentor Influence	Career Influence	Family Influence	Friends/ Respect	Personal Traits	Scientists	Government
1(+)	7(+)	3+	8(+)	15(+)	9(+)	6(+)
2(+)	10+	4+	14(+)	16(+)	11(+)	18(+)
5(+)	13+	12+	19(+)	17(+)	20(+)	21(+)

Scoring method

For positive items (+), responses SA, A, N, D, SD are scored 5,4,3,2, 1, respectively. For negative items (-), responses SA, A, N, D, SD, are scored 1,2,3,4, 5, respectively. Omitted or invalid responses are scored 3.

APPENDIX F

School Teachers (TQ 3) Questionnaire - Attitudes, Personal Traits, Influential Factors

No	Statement	SD	D	U	A	SA
1	This student was motivated to take up science in Years 11 and 12 due to a love for science.					
2	This student was motivated to take up science in Years 11 and 12 with the hope of receiving good results, taking up a science degree in university and obtaining a good job					
3	This student may have been motivated to take up science subjects in Years 11 and 12 because her friends were also choosing the same subjects					
4	The school and the science department played an active role in the success of this student in the HSC and in her choice of a university Course					
5	Science activities, camps, competitions and olympiads, have played a role in motivating this student to take up science in school and to continue to study science in university					
6	This student was strongly supported and encouraged by her family members					
7	This student's mother had a career outside the home, and this served as a motivating factor for her to complete a degree and to have a career					
8	This student's intelligence played a role in her success in the HSC and her university studies.					
9	This student made a consistent effort with her studies and her success in completing her degree is largely due to her hard work.					
10	This student was confident, and this personal trait has helped her to succeed in completing her degree.					
11	This student showed the ability to manage her studies and a part time job and household duties well without getting stressed.					
12	This student was interested in a science related career when she was in school					
13	Friends in the same university have helped this student to persevere with the study of science/ science related course					
14	Old Girls Associations may have helped this student to persevere with the study of science.					

15	Female role models such as scientists, academics and politicians may have influenced this student to persevere and complete her degree					
16	This student's mother did not work outside the home, so she is not likely to do so.					
17	This student may complete her science degree but is not likely to take up a science related- career					
18	This student's family will not encourage her to take up a science degree or career					
19	This student was a good friend to others and encouraged them to take up science and study diligently to complete the course successfully					
20	This student has the potential to take up a science career and may do so but only for a short time. She is not likely to continue once she gets married and has children.					
21	Universities are still male -dominated for science education and therefore these students may face difficulties, coming from a school which had single sex education and female teachers					
22	We have not fully prepared these science students to work independently in the laboratory and on research tasks.					
23	This student does not fully understand the true implications and demands of a science career					
24	Family issues related to financial difficulties or poor health of parents may cause this student to give up her studies and help at home					
25	This student may get distracted from her studies by socializing with friends and going to parties					

Classification of items

Teachers/Mentors	Career	Family	Friends	Personal Traits
4(+)	2(+)	6(+)	3(+)	1(+)
5(+)	12(+)	7(+)	13(+)	8(+)
15(+)	17(-)	16(-)	14(+)	9(+)
21(-)	20(-)	18(-)	19(+)	10(+)
22(-)	23(-)	24(-)	25(-)	11(+)

Scoring method

For positive items (+), responses SA, A, N, D, SD are scored 5,4,3,2, 1, respectively.

For negative items (-), responses SA, A, N, D, SD, are scored 1,2,3,4, 5, respectively.

Omitted or invalid responses are scored 3.

APPENDIX G

Mother (M 4) Questionnaire - Attitudes, Personal Traits, Influential Factors

No	Statement	SD	D	U	A	SA
1	I have had a discussion with my daughter before I signed her form for subject selection for the Preliminary (Year 11) and the Higher School Certificate (NSW)					
2	I have encouraged her to take up at least one science subject in school					
3	I was pleased with the level of science teaching in school and with the practical lessons as well					
4	I felt that there should be a bridging gap between the Higher School Certificate examination and university science degrees					
5	I worked full time while my daughter was studying in school/ university					
6	I worked part time while my daughter was studying in school/university					
7	I did not work outside the home while my daughter was in school/ university					
8	During the Higher School Certificate and university examination periods I gave my daughter extra emotional support.					
9	I expected my daughter to fulfil her household duties during all examination periods.					
10	I was interested in the course she had chosen and discussed with her the job prospects which would be linked to her degree.					
11	I was concerned about whether my daughter would cope with the level of difficulty in her degree.					
12	My managerial skills at home/ at work outside the home served as a role model for my daughter and gave her added confidence in herself					
13	I feel that a science degree is far better for the job market than a non- science degree.					
14	My husband fully supported my daughter in her choice of subjects and the completion of her degree.					
15	I have also completed a science degree and have had a science related career					
16	My daughter was unable to continue with part time work during the examination period.					

17	My daughter showed signs of stress leading up to all examination periods during school and university					
18	I felt that my daughter had received adequate information in school about science degrees and science careers					
19	My daughter was encouraged to attend science career exhibitions and conferences in school					
20	I feel that though my daughter has succeeded in completing her degree, there will not be a suitable career for her in Sydney					
21	My daughter had to learn how to reference using APA / Harvard in University as she had not been taught this is school					
22	The teachers in school and university were very supportive and motivated my daughter to do her best					
23	I feel that people with science careers are paid well in other countries such as England and USA but not in Australia					
24	My daughter was confident and able to organise her studies and her recreation/ part time work well					

Mother (M 4) questionnaire

Classification of Items

Family support	Balance/ stress	Teachers/ Education	Careers
1(+)	9(+)	3(+)	13(+)
2(+)	11(-)	4(-)	15(+)
8(+)	16(-)	18(+)	19(+)
10(+)	17(-)	21(-)	20(-)
12(+)	24(+)	22(+)	23(-)
14(+)			

Scoring method

For positive items (+), responses SA, A, N, D, SD are scored 5,4,3,2, 1, respectively.

For negative items (-), responses SA, A, N, D, SD, are scored 1,2,3,4, 5, respectively.

Omitted or invalid responses are scored 3.

5, 6, 7, (no score- data only)

APPENDIX H

Questionnaire PAU 3

The following questions were asked in a later developed questionnaire to collect specific data.

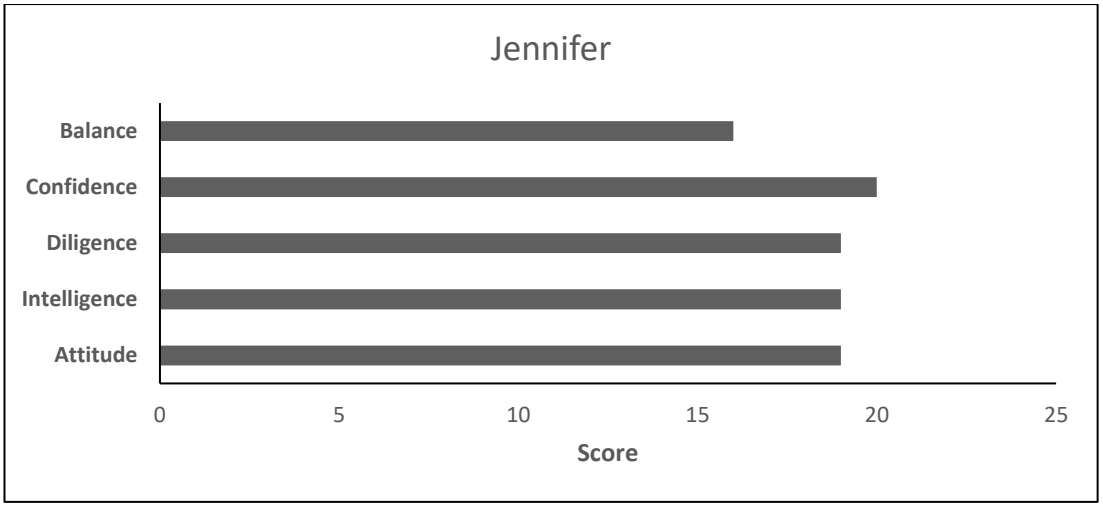
1. Do you work within a study group at university or do you do most of your study individually?
2. Do you share resources? Are you classmates generous with resources?
3. Have you used the method of peer assessment or self -assessment with your assignments?
4. Do your friends discuss your/ their goals for study or career?
5. How often do you meet your university friends socially? Do you keep contact electronically?
6. Do you discuss strategies for dealing with difficulties and obstacles to your study?

APPENDIX I

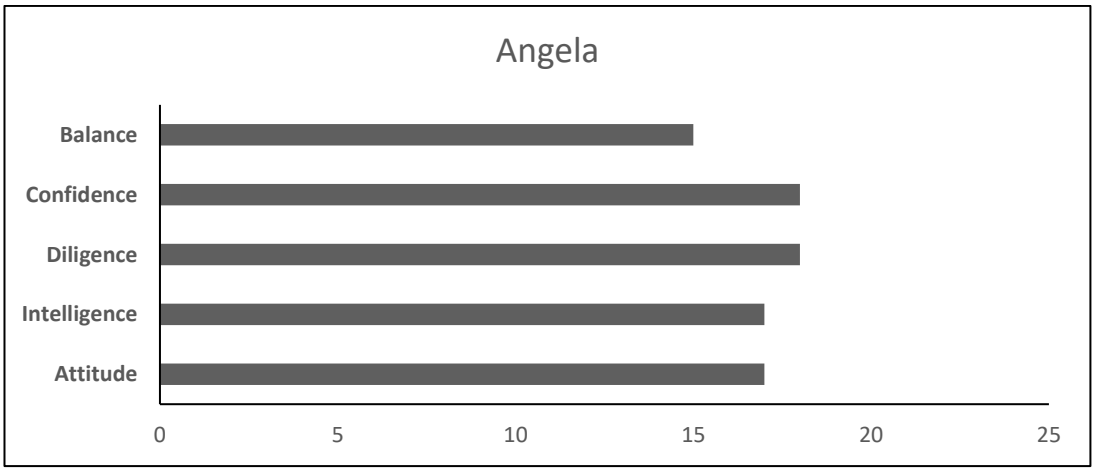
Teacher Profiles for Personal Traits of Participants.

A graphical representation of the specific personal traits from the four teacher scores obtained from Questionnaire TQ 3 allows a cross case analysis of participant abilities (see Table 6.1).

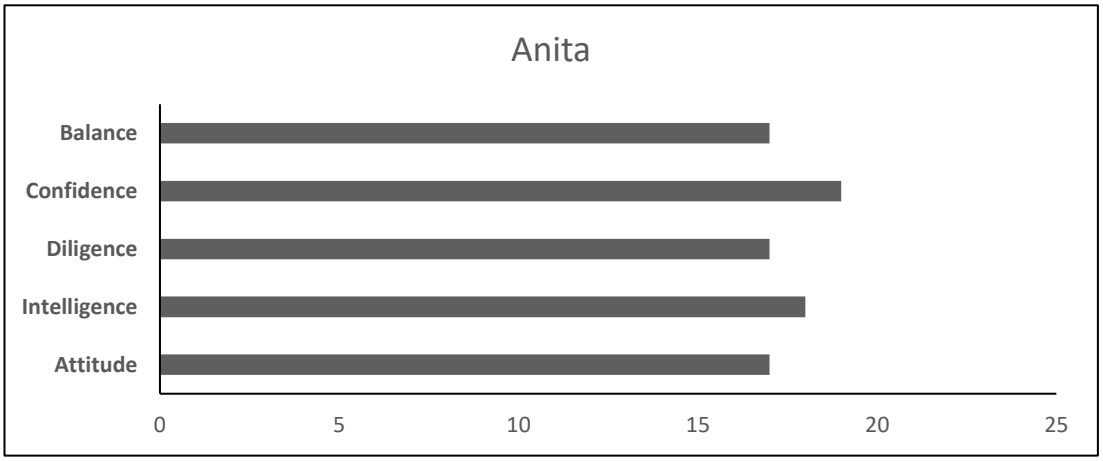
Teacher Profile of Jennifer



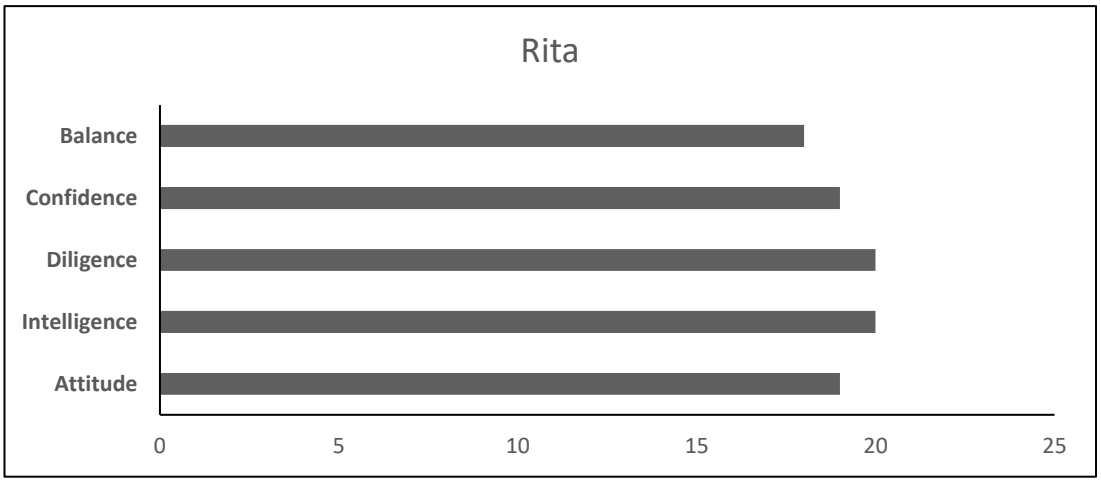
Teacher Profile of Angela



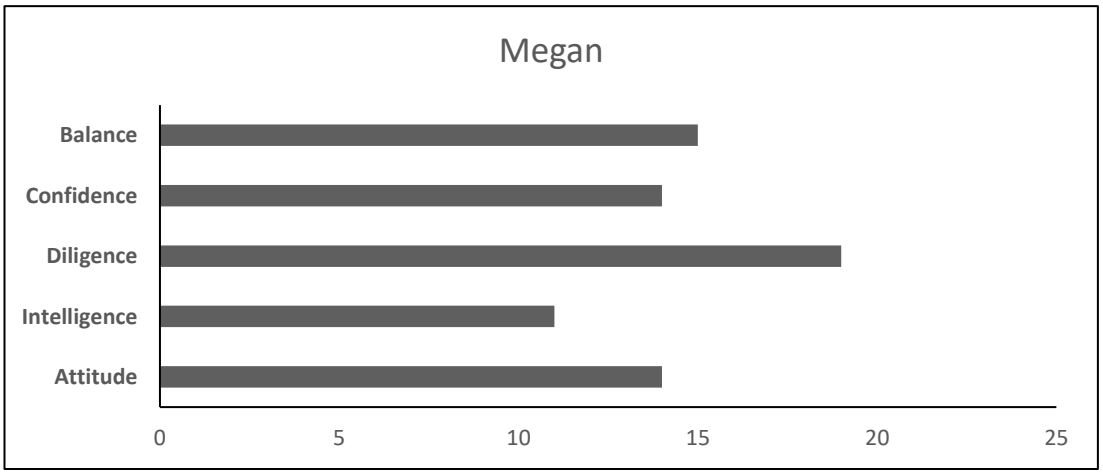
Teacher Profile of Anita



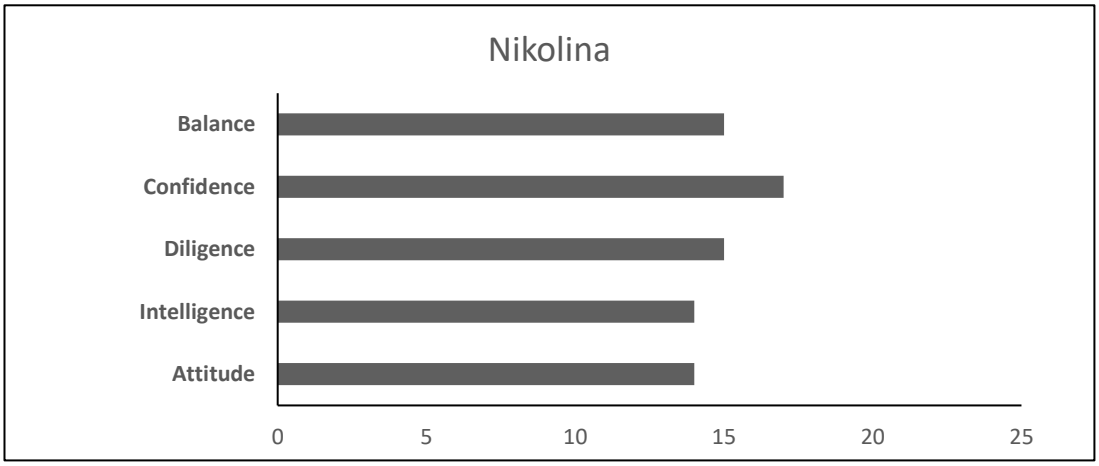
Teacher Profile of Rita



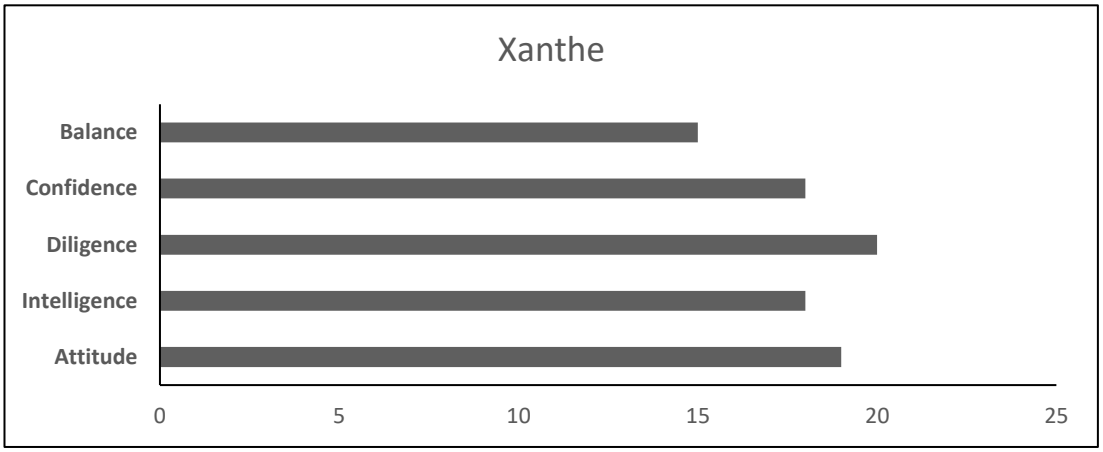
Teacher Profile of Megan



Teacher Profile of Nikolina



Teacher Profile of Xanthe



APPENDIX J

Curtin
University of Technology

Curtin University of Technology
School of Science Mathematics and Engineering
Participant Information Sheet

Project Title: **Perseverance in Science Education**

Researcher:
My name is Isabel Blades. I am undertaking research for my Doctorate in Science Education at Curtin University of Technology.

Purpose of Research:
I am investigating the reasons why students persevere in the study of science.

My Role:
I am interested in finding out why students choose to study science in Years 11 and 12 and continue to do so in university.
I would like to find out if you have chosen a science subject and your reasons for doing so. I would like to ask you questions through interviews and questionnaires.

Consent to Participate:
Your involvement in the research is voluntary. You have the right to withdraw at any stage without it affecting your rights or my responsibilities. When you have signed the consent form, I will assume that you have agreed to participate and allow me to use your data in this research.

Confidentiality:
In adherance to university policy, all information will be kept in a locked cabinet for five years and will be destroyed later. The information you provide, will be kept separate from your personal details.
My supervisor and I will be the only persons who will have access to this.

Further Information:
This research has been reviewed and given approval by Curtin University of Technology, Human Research Ethics Committee, (Approval Number SMEC-03-10). If you would like further information about the study, please contact me on 02 97112060 or by email (isabel.blades@tangara.nsw.edu.au). Alternately, you can contact my supervisor David Treagust on 08 92667924 or email (d.f.treagust@curtin.edu.au).

Thank you for your involvement in this research. Your participation is greatly appreciated.

PARTICIPANT INFORMATION SHEET
PHASE 1

Date:

Introduction:
This questionnaire has been named TOSRA. It will help me to collect information about your attitude towards science. It will take 15 minutes and consists of 30 questions. You may answer it during the lunch break or any other time that is convenient to you.

Please note:

- Taking part is voluntary and you can pull out at any time if you wish to do so.
- Your withdrawal will not affect you in any way.
- Your privacy is greatly respected and any information that could identify you will be removed.
- I have signed a confidentiality form and cannot share information about you with any person.
- All information will be stored in a locked cabinet in my home for 5 years. After this time it will be destroyed.

You may ask questions before during and after the administration of the questionnaire..
Please keep this letter for your information
Thank you for your time

Curtin
University of Technology

CONSENT FORM

- I understand the purpose and the procedures of this study.
- I have read the participant information sheet.
- I understand that my participation is voluntary and that I can withdraw at any time without problems.
- I have been given the opportunity to ask questions and can continue to do so during the study.
- I understand that the procedure may or may not benefit me.
- I understand that no personal information will be used and that I will remain anonymous.
- I understand that information collected will be stored in a safe place for five years and destroyed thereafter.
- I agree to participate in the study outlined to me.

Signature: _____ Date_____

Witness Signature: _____ Date_____