School of Education

Girls and Science: Examining Students' Attitudes and Learning Environment Perceptions

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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 acknowledgement has been made.

This thesis contains no material that has been accepted for the award of any other degree or diploma in any 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-52-12.

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ABSTRACT

Current trends in science, technology, engineering and mathematics (STEM) education show that girls' aspirations for science-related careers are declining and there is a continuously decreasing number of young people, particularly girls, studying science beyond compulsory years and pursuing scientific careers. Given the under-representation of women in STEM professions, this study examined students' experiences of and attitudes towards science classes at school.

The research reported in this thesis drew on an interpretivist paradigm in the design, collection and analyses of the data. A mixed methods explanatory sequential design involved the collection of qualitative and quantitative data in three phases. In the first and second phase, data collection involved administering two surveys: one to assess students' attitudes towards science (known as the Test of Science-Related Attitudes [TOSRA]); the other to assess students' learning environment perceptions (known as the What Is Happening in This Class? [WIHIC] questionnaire). Data collected during these two phases provided a sample of 204 students, who responded to the survey during both phases. This sample included 74 boys and 130 girls drawn from 10 secondary schools in South Australia. The schools included a mix of both all-girls single-sex schools (*n* = 2) and co-educational schools (*n* = 8), and of regional (*n* = 3 co-educational schools) and metropolitan schools (*n* = 7). Following the collection of the quantitative data, the third phase involved the collection of qualitative data using semi-structured interviews with students. This qualitative information was collected from 42 students (*n* = 10 boys and 32 girls).

Initially, because the surveys had not been used previously in South Australia, evidence to support the reliability and validity of the surveys was collected from the participants by the researcher to increase confidence in the subsequent findings. While item analysis (conducted during factor analysis) identified some problematic items, once these items had been omitted, both surveys were found satisfactory in terms of factor structure, internal consistency reliability, ability to differentiate between classes and discriminant validity.

To provide an overview of girl's attitudes towards science classes and their perceptions of the learning environment created in science classrooms in secondary school, descriptive analyses (means, standard deviation) and box and whiskers plots were used. The results indicated that girls enjoyed engaging in scientific inquiry and found great benefit in peer support in the science classroom. The results also indicated that their career interest in science was not favourable, and they did not enjoy engaging in investigation in the science classroom.

To understand in more detail girls' attitudes and their science learning environment perceptions, the study explored different settings for girls. Firstly, it explored co-educational and single-sex settings to determine whether differences existed between girls regarding their attitudes towards science and perceptions of the learning environment. The results indicated differences between girls in co-educational and single-sex settings were positive and statistically significant ($p < .05$) for four out of the five attitude scales (Social Implications of Science, Normality of Scientists, Enjoyment in Science and Career Interest in Science) and three of the seven learning environment scales (Teacher Support, Investigation and Equity). The qualitative data indicated that girls in co-educational settings felt that having boys in the class made science lessons more enjoyable and that girls in a single-sex setting demonstrated more confidence than did their co-educational class counterparts.

To examine girls' attitudes and science learning environment perceptions in different settings for girls, primary and secondary school settings were explored. The differences in scores were positive and statistically significant ($p < .05$) for three of the five attitude scales (Normality of Scientists, Attitude to Scientific Inquiry and Enjoyment of Science Lessons) and for only one learning environment scale (Equity). The qualitative data showed that girls held more favourable attitudes towards scientific inquiry in secondary school compared with primary school. Girls also expressed more positive views of their secondary school science teachers compared with their views of their primary school science teachers, and they viewed the degree to which they were involved in investigations more positively in secondary school.

To improve understanding of how girls can be encouraged to pursue science subjects beyond the compulsory years and engage in scientific careers, the study explored sex differences in co-educational settings. The results found that no attitude scales showed a statistical significance in the differences in attitude scores between boys and girls. However, the qualitative data indicated some sex stereotypes related to the social implications of science and career interest in science. Differences in scores between boys and girls were positive and statistically significant ($p < .05$) for five of the seven WIHIC scales, namely, Student Cohesiveness, Teacher Support, Equity, Task Orientation and Cooperation, and scores were higher for girls than for boys for all seven WIHIC scales. This was an interesting finding demonstrating that although girls have a more positive view of the learning environment and similar attitudes to boys, they are still not choosing to study science (despite having the same level of aspirations for science-related careers).

As a result of this interesting finding, the study then explored whether relationships exist between girls' perceptions of their science classroom environment and their attitudes towards science and achievement. The results indicated statistically significant relationships between the learning environment and four of the five attitude scales (Social Implications, Normality of Scientists, Enjoyment of Science and Career Interest in Science). This suggests that, for the most part, a positive relationship exists for girls between a more favourable classroom learning environment and students' attitudes towards science. Regarding environment–achievement relationships, all seven learning environment scales (Social Cohesiveness, Involvement, Investigation, Task Orientation and Equity) were statistically significantly and positively correlated ($p < .01$) with science achievement. This suggests that, for the most part, a positive relationship exists between a favourable classroom learning environment and students' science achievement, which is therefore a significant factor in relation to encouraging girls to stay in science.

In light of the infrequent research conducted on girls and STEM in Australia to date, this research adds to the body of past global research exploring girls' attitudes towards science and learning environment perception. The results of this study could be of significance to a range of stakeholders, including school leaders, teachers, education systems, universities, professional development providers, curriculum developers and policymakers. The results of this study highlight the need to continue offering and promoting STEM in a gender-balanced way, thereby removing gender stereotypes that may influence future career aspirations and self-belief.

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LIST OF ABBREVIATIONS

ANOVA	one-way analysis of variance
ATSSA	Attitude Toward Science in School Assessment
ACARA	Australian Curriculum, Assessment, and Reporting Authority
CES	Classroom Environment Scale
CLES	Constructivist Learning Environment Survey
CUCEI	College and University Classroom Environment Inventory
ECWiSS	Early Childhood Women in Science Scale
ICEQ	Individualised Classroom Environment Questionnaire
ICSEA	Index of Community Socio-Educational Advantage
KMO	Kaiser–Meyer–Olkin
LEI	Learning Environment Instruments
MANOVA	Multivariate analysis of variance
MCI	My Class Inventory
QTI	Questionnaire on Teacher Interaction
SACE	South Australian Certificate of Education
SLEI	Science Laboratory Environment Inventory
STEM	science, technology, engineering and mathematics
TDSAS	Three-Dimensions of Student Attitude Towards Science
TOSRA	Test of Science-Related Attitudes
US	United States
WIHIC	What Is Happening in This Class?
WiSS	Women in Science Scale

Chapter 1

INTRODUCTION

1.1 Background to the Study

Girls' aspirations for science-related careers are declining and this is evident through current trends in science, technology, engineering and mathematics (STEM) education (Australian Government, 2017; Kinskey, 2020; Office of the Chief Scientist, 2020). These trends reveal a continuously decreasing number of young people pursuing scientific careers and studying science, particularly girls (Australian Government, 2017; Kinskey, 2020; Office of the Chief Scientist, 2020). In 2017, the top 10 career aspirations for Australian adolescent girls included teaching, nursing and beauty and STEM subjects did not appear. In contrast, boys' top 10 career aspirations included science, information and communications technology, engineering and transport. The lack of these areas on the girls' list is concerning.

Although there has been an increase in women in the STEM workforce in recent years, women remain under-represented in many STEM professions (Campanini, 2020; Hill et al., 2010). In Australia, girls do not participate in STEM as heavily as boys, and they also have lower STEM aspirations when compared with boys (Department of Industry, Innovation and Science, 2020). Studies show that girls' and women's interest and engagement in science and mathematics decreases throughout their education, with only 28% of women making up the STEM workforce in the United States (US) and 32% in Australia (e.g., Australian Government, 2019; Campanini, 2020; Office of the Chief Scientist, 2020). This gender gap is even higher in fields such as computer science and engineering (Australian Government, 2019). Further, many gender stereotypes still exist within the STEM fields, with people continuing to view them as masculine and underestimating girls' abilities in these fields (Carlone, 2004; Holmes et al., 2017). Contributing to the under-representation of women in STEM may be girls' science learning environments. Current research shows that the learning environment around them shapes girls' achievements and interest in science and that gender stereotypes in these fields continue to lower girls' aspirations for science careers over time (Hill et al., 2010). There is a connection between early attitudes about careers and later career and education decisions (DeWitt et al., 2013).

Addressing gender inequities in STEM is a crucial challenge for all countries, including Australia (Hussénius, 2020). In Australia, the government has highlighted that action is needed to ensure a gender balance in STEM. To achieve this, the Australian Government has implemented many initiatives in recent years to support girls and science. These include the *Girls in STEM Toolkit* (Australian Government, 2021a*)*, aimed at encouraging girls to study and pursue careers in STEM; the *Advancing Women in STEM Strategy* (Australian Government, 2019), aimed at increasing gender equity in STEM education and careers; and the *Women in STEM Ambassador* program (Australian Government, 2021b), aimed at promoting awareness of STEM careers and at gender-inclusive STEM education for boys and girls. In addition to these initiatives, the *National Science Statement* (Australian Government, 2017) articulates the need to expand girls' capability in STEM.

Past research has found that attitudes towards science and science careers start to form early, before the post-compulsory years (DeWitt et al., 2013; Murphy & Beggs, 2003). Research has also shown that as students enter their later primary years and middle years, they rapidly lose interest in science-related careers (Potvin & Hasni, 2014). To help address the under-representation of women in STEM fields, this study focused on girls and science as they reach a critical period of their education – their secondary years.

My interest in this study grew from my years teaching in a secondary science classroom at the point of transition from primary to secondary school. This teaching was in an all-girls setting. I experienced many conversations, differences in contexts and stories of students who had just arrived in the secondary setting. In this context, students shared their varied experiences of science, attitudes towards science and career aspirations. It became apparent that many girls did not view themselves as scientists and did not aspire to science careers. Another point of interest was sharing their diverse primary school classroom environments and how this influenced their engagement and attitudes towards science. I was in a privileged position in which I witnessed their excitement in engaging with the science classroom learning environment in a secondary setting. (See Chapter 3 for my positionality statement.)

This study helped to build a picture with respect to girl's attitudes towards science classes and their views of the context or learning environments. Given the under-representation of women in STEM professions, this study examined students' experiences of and attitudes towards science classes at school and how this might contribute to this decline. It helped explain how educators might improve the experience for girls in ways that encourage a continued interest in science beyond the compulsory years.

This chapter introduces this thesis under the following headings:

- Context of the Study (Section 1.2)
- Theoretical Framework (Section 1.3)
- Research Questions (Section 1.4)
- Significance of the Study (Section 1.5)
- Overview of the Thesis (Section 1.6).

1.2 Context of the Study

This section briefly describes South Australia and the various education sectors within the state. South Australia occupies the southern central region of Australia and is one of states and territories. The population of South Australia is over 1.7 million, which accounts for 7.14% of the Australian population. The majority backgrounds for the South Australian population include English, Scottish, German and Irish, with the top languages including English, Mandarin, Vietnamese, Italian, Greek and Cantonese.

In South Australia, there are four major transitions in education: firstly, the transition from home to kindergarten or pre-school; secondly, kindergarten or pre-school to primary school; thirdly, the transition from primary school to secondary school; and lastly, the transition from secondary school to tertiary education. At the time of conducting this study, secondary school began in Year 8 in South Australia. However, South Australia is currently at a point of change and transition. This transition means that by the end of 2021, secondary school in South Australia, for all sectors (independent, Catholic and public), will begin in Year 7. In South Australia, primary schooling begins at the reception level, with completion at secondary school being in Years 12 and 13.

The responsibility for providing education to Australian children rests with the states and territories. They meet their commitment to universal access to education through the provision of public education. Two main systems operate in South Australia: the public sector, which sources most of its funds from the state government, and the private sector, which the Commonwealth government funds. The private schools are primarily faith-based and rely on both Commonwealth funding and parent contributions. In South Australia, there are 511 government schools, 101 Catholic schools and 103 independent schools (Australian Bureau of Statistics, 2019).

Government schools in South Australia filter their enrolment through school zones and catchment areas. A ‘school zone’ includes a geographical area that surrounds the school and from which the school accepts enrolment. A ‘catchment area’ is a geographical area. Government schools give priority enrolment to children who live inside that zone or catchment area. Most secondary schools in metropolitan Adelaide are zoned, and several primary schools are zoned. Some schools have a shared zones or catchment areas, allowing students living in this zone to nominate a preferred local school surrounding an unzoned school that is closest by road (Department for Education, 2021). The independent and Catholic sectors are fee-paying and are not geographically zoned. The schools within these systems are either co-educational or single sex. In Australia, there are more single-sex schools for girls than boys (Forgasz & Leder, 2017). In South Australia, 94% of schools are co-educational, 4% are single-sex all-girls, and 3% are single-sex all-boys schools (The Good Schools Guide, 2016). Most single-sex schools within Australia and South Australia, in the fee-paying sector, are within the independent and Catholic sectors. Within the Government sector, entry into single-sex schools is generally selective and based on academic achievement (The Good Schools Guide, 2016). In fee-paying schools, academic scholarships are available, and some students utilise these. However, many students attending single-sex schools are generally from higher socio-economic backgrounds than are those attending government schools.

The national curriculum, developed by the Australian Curriculum, Assessment, and Reporting Authority (ACARA), is utilised in most Australian schools, including those in South Australia. Australia's national curriculum is called the Australian Curriculum. In South Australia, the Education Standards Board ensures all schools (in all sectors) effectively deliver the Australian Curriculum. In South Australia, science is taught through the Australian Curriculum and is presented as a developmental sequence of learning from Foundation to Year 10. Therefore, it is compulsory to teach and learn science until Year 10. This compulsory curriculum

> provides opportunities for students to develop an understanding of important science concepts and processes, the practices used to develop scientific knowledge, of science's contribution to our culture and society, and its applications in our lives. The curriculum supports students to develop the scientific knowledge, understandings and skills to make informed decisions about local, national and global issues and to participate, if they so wish, in science-related careers (Australian Curriculum Assessment and Reporting Authority, n.d, learning areas, para. 14).

From Year 10 onwards, students engage in the senior secondary subjects of biology, chemistry, earth and environmental science, and physics as part of the South Australian Certificate of Education (SACE). Most students complete Stage 1 in Year 11, and Stage 2 is typically undertaken in Year 12. To complete their SACE, students must achieve at least 200 credits. For a full-year subject, students receive 20 credits, and for a one-semester subject, they receive 10 credits. SACE data for 2020 show that boys elected to undertake more science subjects compared with girls, as summarised below:

- For 10 credit Stage 1 (Year 11) science subjects, 49% of girls elected to take science subjects compared with 51% of boys.
- For 20 credit Stage 1 subjects (Year 11), only 24% of girls elected to take science subjects compared with 76% of boys.
- For 10 credit Stage 2 (Year 12) science subjects, 43% of girls elected to take science subjects compared with 57% of boys.

- For 20 credit Stage 2 (Year 12) science subjects, 59% of girls elected to take science subjects compared with 41% of boys.
- Interestingly, for the 10 credit Stage 2 (Year 12) subject of 'STEM and the Community', no girls enrolled in this compared with 100% of boys.
- For the 20 credit Stage 2 (Year 12) subject of 'STEM and the Community', 34% of girls elected to take this topic compared with 66% of boys.
- Lastly, for the 20 credit Stage 2 (Year 12) subject of 'Science, Technology and the Community', only 19% of girls enrolled in this topic compared with 81% of boys.

This data reiterates the decreasing number of young girls pursuing scientific careers and studying science.

1.3 Theoretical Framework

This section identifies the theoretical frameworks that underpinned this research. Firstly, Section 1.3.1 discusses the paradigm chosen for this study, the interpretivist paradigm. Section 1.3.2 discusses the strategy of combining qualitative and quantitative data, the mixed methods approach, which was used in this study.

1.3.1 Interpretivist Paradigm

This section explores the research paradigm used throughout this study, the interpretivist paradigm. In this section, interpretivism is defined and a discussion of how this paradigm underpins and informs the mixed methods approach adopted in this study is provided. Interpretivism is informed by philosophies such as phenomonenology and hermeneutics (Schwarz-She & Yanow, 2020), in which the nature of reality is socially constructed. As a methodolocical approach, the purpose of research grounded in the interpretivist paradigm is to reflect the understanding of participants by focusing on the context, and acknowledging that knowledge and truth are based on unique experiences and understanding (Ryan, 2018). It focuses on understanding the stakeholders' understanding of a particular context and emphasises this expressed understanding rather than discovering universal laws or rules (Willis, Jost & Nilakanta, 2007). The knowledge arising from interpretivist research is integrally linked to the participants and the research context, meaning that the results are contextually rich (McChesney & Aldridge, 2019). Willis, Jost & Nilakanta (2007) explains interpretivists views on research below:

Interpretivists accept almost all the types of quantitative methods that positivists use, but they differ in how they interpret the results of quantitative research. Quantitative research is one of many potential sources of understanding. Moreover, in many cases, quantitative research is not the preferred mode of research. Interpretivists also use a broad range of qualitative methods. (Willis, Jost & Nilakanta, 2007, p. 110).The interpretivist paradigm informed the design, collection and interpretation of data in this study, with the overarching focus being on girls' attitudes towards science and their learning environment perceptions. Therefore, the research design needed to explore students' experiences and perceptions deeply, capturing authentic student voices. Using an interpretivist stance allowed me to understand the multiple realities described by the students in a particular context (Willis, Jost & Nilakanta, 2007). Willis, Jost & Nilakantam (2007) argued that for interpretivists, understanding the world to which a person belongs is essential to good research in the social sciences. The interpretivist paradigm was employed as I tried to make localised meaning through the participants' experiences. This study considered the various experiences and contexts to which students were exposed in science classes, as recommended by Ryan (2018).

I adopted an interpretivist stance to allow me to understand the world of the students as they understood it, rather than change or provide a universal law. Using interpretivism enabled me to view reality as complex, and to appreciate that a single phenomenon can have multiple interpretations. For this reason, the post-positivism, transformative and pragmatic paradigms were not employed in this study.

Research has shown that the interpretivist paradigm can underpin and inform the whole of a mixed methods study, and McChesney and Aldridge (2019) demonstrated that a holistic paradigmatic stance (specifically, the interpretivist stance) can be used to frame a mixed methods study. Moreover, research has demonstrated that quantitative methods and concepts such as 'impact' and 'differences' can be incorporated into an interpretivist study (McChesney & Aldridge, 2019).

In this study, the research questions were examined using quantitative and qualitative methods, which allowed me to produce similar results from methods with different strengths, thereby cross-validating the data (Morgan, 2014). The quantitative and qualitative data were analysed in a complementary manner. I was able to use the results from the qualitative interviews to elaborate, enhance and clarify the results from the quantitative survey results (Halcomb & Hickman, 2015). For my study, the interpretivist paradigm and mixed methods approach selected were considered suitable because they allowed the aims and objectives of the study to be met.

1.3.2 Combining Quantitative and Qualitative Methods

Much past research has indicated that combining qualitative and quantitative research methods within classroom environments and in other fields is beneficial. Usually, qualitative methods involve researchers visiting the class and frequently interviewing students, teachers, parents and school administrators throughout the study. Generally, data from questionnaires, which represent the quantitative data, guide the collection of the qualitative data. Combining both quantitative and qualitative methods is becoming more common (Kagesten et al., 2016; Khalil, 2015; McChesney, 2017; Ogbuehi, 2006; Sirrakos & Fraser, 2017; Ribbons, 2015) and has many proven benefits (Caruth, 2013; Creswell, 2008).

Gathering qualitative data through interviews provides a deeper understanding of the participants’ learning environment (Afari, 2012; Almasi & Zhu, 2020; Cho et al., 2021; Martin-Dunlop & Fraser, 2008; McChesney, 2017; Ogbuehi, 2006). International studies conducted in the United Arab Emirates (Afari, 2012; Khalil, 2015; McChesney, 2017), Germany (Sirrakos, 2012) and the US (Martin-Dunlop, 2004, 2013) have explored classroom learning environments combining qualitative and quantitative methods.

Different mixed methods designs may be utilised, and each design has a unique approach and apportions varying weights to the qualitative and quantitative data. In this study, I utilised an explanatory sequential design. The mixed methods explanatory sequential design consists of two distinct phases: quantitative and qualitative data collection (Creswell et al., 2003). The follow-up explanations model was used to enable me to identify specific quantitative findings that required additional explanation. Following this identification, I collected qualitative data from participants who could best help explain those findings.

Although combining quantitative and qualitative methods is becoming popular in current research, there has been minimal research in the field of science classroom learning environments using a mixed methods approach in the past decade, particularly in Australia. My study fills this gap.

1.4 Research Questions

Girls' attitudes towards science and their learning environment perceptions are important to examine when exploring how to encourage girls to develop an interest in pursuing science, both in their secondary years and beyond (Aldridge & Rowntree, 2021; Eccles, 2007; Fraser & Raaflaub, 2013). Two surveys were used in this study, one to assess attitudes towards science and one to assess learning environment perceptions. The survey used to assess attitudes has been extensively field tested and has been proven reliable both in Australia and overseas (Fraser, 1981; Fraser, Aldridge, & Adolphe, 2010). The survey used to assess learning environment perceptions has been found valid and reliable when used in several countries (Dorman, 2003) and with various subject areas (Aldridge & Fraser, 2000; Aldridge et al., 2006; Margianti et al., 2001; Zandvliet & Fraser, 2005). These studies used various samples, including secondary school students (Aldridge et al., 1999; Dorman, 2003), pre-service teachers (Martin-Dunlop, 2013) and kindergarten students (Robinson & Fraser, 2013). Given the two surveys used in this study had not been used with this population before, as a first step, the study sought to provide evidence to support the reliability and validity of the instruments when used with this sample. Therefore, the first research question asked:

Are the instruments used to assess students' attitudes towards science and their perceptions of the learning environment valid and reliable when used with secondary school students in South Australia?

Young girls are continuing to display a lack of interest, engagement and success in STEM disciplines (Kinskey, 2020) and are rapidly losing interest in science-related careers as they progress towards the end of middle school (Potvin & Hasni, 2014). Past studies have indicated that students' interest and attitude towards science declines from the beginning of secondary school. Therefore, the second research question specifically focused on girls in secondary school to gain a clearer understanding of the factors that contribute to these findings and trends. The second research question asked:

What attitudes do girls hold towards science, and how do they perceive the learning environment in secondary science classes?

There has been a long-standing debate concerning whether single-sex education or co-education has more favourable outcomes for students. The third research question sought to understand how single-sex and co-educational settings affect attitudes towards science and learning environment perceptions. Therefore, the third research question asked:

Do differences exist between girls in co-educational and single-sex schools in terms of their attitudes towards science and their learning environment perceptions?

While researchers continue to explore and better understand girls' attitudes towards science and their learning environment perceptions, it was important to examine and compare various science learning environment settings. Over the past 30 years, there has been interest in the effects of adolescents' transition from primary school to middle school or secondary school (Fraser, 2012). This interest has grown over the last decade and further research at the point of transition has been undertaken. Research has suggested that changes in learning environments across the transition and the role of the teacher within those environments can have lasting detrimental effects on student attitudes, especially for girls (Speering & Rennie, 1996). Therefore, the fourth research question asked:

Do girls' attitudes towards science and their perceptions of the learning environment differ between primary and secondary school settings?

Given the continuously decreasing number of girls pursuing scientific careers and studying science, it was important to explore how and if gender contributes to this decline. Past research has suggested that gender influences students' general perception of science and their experience of science (Eccles, 2007; Kelly, 1987; Oakes, 1990). It also shows that students of different gender perceive the learning environment differently (Eccles, 2007; Fisher et al., 1997; Fraser & Raaflaub, 2013; Li & Singh, 2021; Midgley et al., 1991; Peer, 2011). Therefore, the fifth research question asked:

Do differences exist between girls and boys in secondary school in terms of their attitudes towards secondary school science classes and their perceptions of the learning environment?

To build a picture of how girls can be encouraged to pursue scientific careers and the study of science, it was important to explore the relationship between attitudes and science classroom learning environments. Research has revealed a direct correlation between classroom learning environments and attitudes. Further to this, research demonstrates that the classroom learning environment influences the affective and cognitive outcomes of students (Aldridge & Fraser, 2008). Moreover, results of studies have consistently found positive relationships between the learning environment and a range of outcomes (Adamski et al., 2013; Lee, 2010; Madu, 2010; Rucinski et al., 2018). Therefore, the sixth research question asked:

Do relationships exist between girls' perceptions of their science classroom environment and their:

- *attitudes towards science and*
- *science achievement?*

1.5 Significance of the Study

This section provides a brief overview of the significance of this study with a focus on why this research is important to improve understanding of how girls can be encouraged to pursue science (see Chapter 5 for more details).

The points below summarise the significance of this study's findings:

- This study holds significance for policymakers, curriculum developers, professional learning providers, teachers and school leaders in promoting STEM, particularly for girls.
- The study highlights the importance of presenting science as equally appropriate for girls and boys.
- This study provides practical insights for educators regarding how classroom environments in both the primary and secondary years affect attitudes towards science; such information has the potential to inform transition programs and career aspirations in science.
- The study holds potential significance for the STEM workforce, providing insights into the importance of the career sector engaging and supporting girls in science when they reach high school to foster and inspire career aspirations in STEM fields.

1.6 Organisation of the Thesis

Chapter 1 highlighted the importance of STEM and science education and stated that girls are currently under-represented in STEM fields. It provided the context of the study and reviewed the structure of schools in South Australia. It discussed the theoretical framework and research paradigm adopted in the study and highlighted the research questions. Finally, it discussed the significance of the study.

Chapter 2 provides a comprehensive review of the literature. Section 2.2 begins by reviewing the literature related to girls and science. Within this section, I highlight current trends in science and STEM, along with efforts made to achieve equitable outcomes for girls, with a focus on careers and achievement. Following this, Section 2.3 reviews the literature related to girls in different settings. Here, I explore research related to single-sex education and co-education, followed by research related to primary and secondary school settings. Section 2.4 investigates attitudes towards science, defining the term 'attitude' and exploring past research about girls' attitudes towards science. I then review the literature related to the instruments used to assess attitudes towards science. Finally, Section 2.5 provides a literature review related to learning environment perceptions. I explore the history of learning environments in this section and then review past learning environment research. Following this, I provide a review of the literature related to the development of learning environment instruments.

Chapter 3 provides the methodology employed in the study. Section 3.2 begins by detailing the research questions in the study. Following this, Section 3.4 details the research design including the research paradigm and mixed method design. Section 3.5 explains how the sample for the study was selected including the selection of schools and sample for both the quantitative and qualitative data collection. Following this, Section 3.6 describes the instruments used to collect data at different phases of the study. Following this, Section 3.7 details the different analyses used to answer each of the research questions. Finally, Section 3.8 provides a detailed account of the considerations made to address ethical issues pertinent to my study.

Chapter 4 reports the results of my investigations. Section 4.2 begins by reporting results pertinent to each research question beginning with the validity and reliability of the instruments. Following this, Section 4.3 reports girls' attitudes towards science and their perceptions of the science learning environment in secondary school. Section 4.4 reports the differences between co-educational and single-sex settings and between primary and secondary settings. Following this, Section 0 reports sex differences for girls and boys in terms of attitudes towards science and perception differences in secondary school science classes. Finally, Section 4.6 reports relationships between learning environment, attitudes towards science and achievement in relation to girls.

Chapter 5 concludes the thesis. Section 5.2 begins by providing a summary and discussion of the major findings of the study. Following this, Section 5.3 details the limitations of the study. Section 5.4 summarises the recommendations for future research and Section 5.5 discusses the significance of the study. Finally, Section 5.6 provides concluding remarks.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

The focus of this study was to gain a better understanding of girls' experiences of science classrooms in different contexts, with a view to improving girls' experience and encouraging their aspirations to pursue science. In particular, this study examined girls' attitudes in different contexts and the types of learning environments that might enhance those attitudes. This chapter reviews the literature related to the major variables explored in the study, which are presented under the following headings:

- Girls and Science (Section 2.2)
- Science for Girls in Different Settings (Section 2.3)
- Attitudes Towards Science (Section 2.4)
- Learning Environment Perceptions (Section 2.5)
- Chapter Summary (Section 2.6).

2.2 Girls and Science

In this section, a review of the literature related to girls and science is provided. It explores the current trends in science and STEM and research related to achieving equitable outcomes for girls, with a focus on careers and achievement.

The *National Science Statement* defines science as

> natural, physical and life sciences, including medical and health sciences, mathematics, engineering, and technology-related disciplines. This definition includes the full spectrum from basic to applied scientific research in both the public and private sectors and the infrastructure, skills, institutions, knowledge, and policies that make it possible. (Australian Government, 2017, p. 4)

With this definition in mind, when discussing the importance of science in this thesis, this also includes the importance of STEM. According to the *National Science Statement* (Australian Government, 2017), involvement in STEM subjects in Australian schools has decreased, with enrolments being lowest in the last two decades. Further, young people, particularly girls, continue to display diminished interest and achievement in science and STEM fields (Kinskey, 2020) and are rapidly losing their interest in these science-related careers as they progress towards the end of middle school (Potvin & Hasni, 2014).

The Australian Chief Scientist argued that STEM skills are in high demand for the future workforce, highlighting the importance of developing these skills through education (Office of the Chief Scientist, 2020).

Australia's chief, scientist Dr Alan Finkle, stated that

> it is predicted that now and into the near future, the largest jobs growth will be in health care followed by professional, scientific and technical services, construction, and education and training. Employment is expected to grow strongly in the computer system design sector by 25%, but this is not replicated across a broader range of traditional STEM careers. (Educational Council, 2018, p. 24)

Science is a critical component of STEM, and while the demand for professionals in the areas of STEM is rising (Office of the Chief Scientist, 2020), women continue to be under-represented in STEM fields (Australian Government, 2019; Campanini, 2020). The distribution of STEM-qualified males and females has not changed substantially since 2006 (Office of the Chief Scientist, 2020). Females constitute just over a third (36%) of the young STEM-qualified population for those with university qualifications (Office of the Chief Scientist, 2020). Further, past reports indicate that, with respect to the continuously decreasing number of young people pursuing scientific careers and studying science, this is particularly the case for girls (Australian Government, 2017; Kinskey, 2020; Office of the Chief Scientist, 2020).

Despite efforts to encourage students to pursue science, current trends in STEM education reflect these trends in employment, with research indicating that girls' aspirations for science-related careers are declining. Australia is currently seeking ways to scientifically engage and encourage young people to pursue scientific studies and careers (Australian Government, 2017). The *National Science Statement* clearly states the importance of engaging the Australian community in STEM, which involves targeted education and career development processes (Australian Government, 2017). The Australian Government's 'science agenda' focuses on expanding STEM capability, as set out in the *National Science Statement* (Australian Government, 2017).

However, regardless of the science agenda, there continues to be an issue regarding career aspiration for girls. Even girls who perform well academically are less likely than boys to expect to work in a science-related occupation (Organisation for Economic Co-operation and Development, 2020). Australia's Chief Scientist, Dr Alan Finkle (Office of the Chief Scientist, 2020), also stated that concerning the capacity of Australian school students to meet this demand, data show that girls are under-represented in STEM fields. In 2019 and 2020, the Australian Department of Industry, Innovation and Science tracked young Australians' understanding and perceptions of STEM education and related careers. When asked about careers, around a third of young people were considering a role in STEM in the future, with 41% being boys and 24% being girls. The research from the 2019 and 2020 study reflects the under-representation of girls' aspirations towards STEM and reports that the STEM gender gap becomes more pronounced as girls become older (Department of Industry, Innovation and Science, 2020).

The *National Science Statement* highlights that girls and women have lower involvement in many areas of science (Australian Government, 2017; Kinskey, 2020), rendering the research in the current study not only timely, but also critical. If girls are to be encouraged to pursue science as they progress through their secondary and tertiary education, educators and schools will need to consider ways to enhance favourable attitudes, perhaps by improving the context of learning. There is a need to understand better why some of these trends are occurring and how solutions might be found to these challenges. Given an essential goal of science education is to nurture students' positive attitudes towards science (Navarro et al., 2016), this study builds on many years of research in this area (e.g., Barmby et al., 2008; Belfi et al., 2012; Burns et al., 2016; DeWitt et al., 2013; Kahle & Lakes, 1983; Kaya & Kaya, 2020; Kennedy et al., 2016; Murphy & Beggs, 2003; Potvin & Hasni, 2014, Power, 1981; Rusmana et al., 2021; Sheldrake et al., 2019; Sikora, 2014; Speering, 1996).

As outlined in the paragraphs above, girls are under-represented not only in STEM-related professions but also in school science in the later stages of high school (when science is no longer compulsory) and tertiary education settings. Research has suggested that STEM disciplines are viewed as challenging and complex, which may be one of the reasons that more boys have STEM-related career aspirations compared with girls (Holmes et al., 2017). Further, STEM-related careers are often viewed by society as mainly male oriented (Hill et al., 2010).

Studies have also shown that even though a large percentage of girls demonstrate strength in science, this does not equate to them graduating or pursuing a career in the STEM fields (Stoet & Geary, 2018). Further, studies have reported that students' science achievement is positively related to their STEM career aspirations, that is, the better students do in science, the more likely they are to select a science-related career (e.g., Cairns & Dickson, 2021). However, research findings have also suggested that this positive relationship is stronger for boys compared with girls, suggesting that perhaps achievement is not as important to girls when selecting a science-related career. Moreover, research has reported that, even though promoting and encouraging girls into science classes can improve their attitudes towards science lessons, it is unlikely to change their career aspirations (Darke et al., 2002). The findings of these and other studies suggest that the career aspirations of girls are likely to be influenced by social, cultural and structural factors (Osborne et al., 2003; Smith, 2010) rather than by achievement or ability (Tytler et al., 2008).

Interestingly, research findings have suggested that teachers' views of girls' ability in science may contribute to their career aspirations. Findings have noted that many teachers attribute girls' high achievement in science to their plodding diligence; however, in comparison, they attribute boys' achievement in science to raw talent (Carlone, 2004). For these teachers, even when girls achieve better grades than boys, girls are not regarded as having raw ability (Carlone, 2004). Further, the results of past studies suggest that, despite the expectations of many teachers for boys to perform better than girls in science, this attribution might well be gender biased (Zhao et al., 2021). In support of this, Zhao et al. (2021) proposed that boys only demonstrate higher science achievements than girls' achievements when boys feel that they possess higher science abilities. These studies show the importance of teachers being aware of gender differences in achievements and the importance of developing strategies to facilitate young girls' learning and achievement in science to ensure equitable outcomes.

My study built on these past studies by examining factors that might promote and nurture equitable outcomes for girls. Given that students' interest in STEM disciplines in early secondary school is a key predictor of career interest (Sadler et al., 2012), my study examined how different settings might influence students' attitudes towards science and how teachers might adapt the learning context to engage students' interest and maintain achievement levels in science from an early age,

2.3 Science for Girls in Different Settings

To improve understanding of how teachers and schools can support girls in science, this study examined students' attitudes towards science and their perceptions of the learning environments created in different settings. This section reviews the literature related to science for girls in different settings. Firstly, it explores research related to single-sex education and co-educational (Section 2.3.1) and then research related to primary and secondary school (Section 2.3.2).

2.3.1 Single-sex Education and Co-education

A long-standing debate exists regarding whether single-sex education or co-education has more favourable outcomes for students (Belfi et al., 2012; Brutsaert & Van Houtte, 2002; Kombe et al., 2019; Koniewski & Hawrot, 2021; Monaco & Gaier, 1992; Pahlke & Hyde, 2016; Sikora, 2014) and, although some research has been conducted in this area over the last two decades, it has been limited and the findings have been inconclusive. Research has been undertaken globally exploring the benefits of single-sex schooling, particularly for girls. Some studies have found that single-sex settings positively influence girls' behaviours and abilities in science (Belfi et al., 2012; Sikora, 2014) and their career aspirations and achievement (Koniewski & Hawrot, 2021; Monaco & Gaier, 1992). Moreover, in single-sex classrooms, girls experience a higher sense of belonging and feel more socially accepted (Belfi et al., 2012). Research has reported that single-sex classes provide a foundation of social commonality for girls (Brutsaert & Van Houtte, 2002). It has also been suggested that in co-educational classrooms girls are confronted with an affiliation–achievement conflict, whereby they feel they need to fulfil academic achievement expectations while still fulfilling their gender-oriented need for social acceptance (Belfi et al., 2012). Research has also indicated that girls in single-sex schools appear to possess high self-regard and self-confidence and a high level of vocational maturity (Monaco & Gaier, 1992).

In contrast, other studies have found little or no differences regarding students' academic self-belief between girls in the two different settings (Pahlke et al., 2014). Pahlke et al. (2014), in their meta-analysis of 184 studies, synthesised results of various international research, comparing single-sex education with co-education, finding multiple student outcomes, including in relation to science performance and attitudes. Regarding science performance, the authors found that the wed effect sizes for controlled studies suggested a close to zero difference between single-sex schooling and co-educational schooling in science performance among girls. They also found an insufficient number of controlled studies had been conducted to examine the difference between single-sex and co-educational schooling regarding girls' science attitudes. The uncontrolled averaged effect sizes indicated that the difference between single-sex and co-educational schooling in science attitudes was small for girls, with girls in single-sex schooling reporting more positive attitudes towards science than girls in co-educational schooling. This large meta-analysis concluded that single-sex schooling generally produced only trivial advantages over co-educational schooling, with the most wed effect sizes being smaller than 0.10.

Other research has examined the socio-economic backgrounds of girls in single-sex and co-educational settings. The fee-paying sectors of education in Australia include many single-sex schools (Forgasz & Leder, 2017). Moreover, students at these schools are usually from higher socio-economic backgrounds than students attending public schools (Australian Bureau of Statistics, 2006). Therefore, it is harder to determine whether socio-economic factors or classroom learning environment contribute to students' perceptions. Halpern et al. (2011) argued that socio-economic status, school-level resourcing and other factors influence the educational benefits of single-sex education (Halpern et al., 2011).

Past research has indicated that girls in single-sex settings hold higher achievement aspirations (Monaco & Gaier, 1992). However, other studies have suggested that single-sex schooling lacks scientific support and may exaggerate sexism and gender stereotyping (Halpern, et al., 2011). Overall, past research has indicated only minor advantages of either setting. Further, it has been argued that single-sex schools are no better in terms of achievement than co-educational schools (Pahlke et al., 2014).

This section has highlighted that although past research has explored differences between single-sex and co-educational settings, particularly for girls, the findings are inconclusive. Further, past research has not focused on girls in science or whether these settings make a difference in terms of career aspirations. Therefore, the study reported in this thesis builds on this past research and contributes to our current understanding of how or whether girls' attitudes towards science and their perceptions of the context of learning differ between single-sex education and co-educational settings. Understanding the influence and impact of these settings is important to improve understanding of how best to support girls in science.

2.3.2 Primary and Secondary Settings

The study also examined girls' attitudes towards science and their views of the learning environment in primary to secondary school settings. Examining these two settings is important given the results of past studies indicate that students' interest in and attitude towards science declines when they start secondary school. These findings suggest that the formation of children's science aspirations occurs during the 10 to 14 age period (DeWitt et al., 2013). Burns et al. (2016) showed that children's interest in STEM careers changed throughout their secondary schooling, with their interest in science declining from middle school, and the most significant decline happening for girls.

Much science education research has focused on late elementary and middle school students (e.g., grades 5–8) because students rapidly lose interest in science-related careers as they reach the middle and secondary years (Barmby et al., 2008; Kahle & Lakes, 1983; Potvin & Hasni, 2014, Power, 1981, Speering, 1996). Of concern are findings that students' attitudes towards school science decline even throughout primary school (Murphy & Beggs, 2003).

Various studies have explored how the different years of schooling can affect boys' and girls' attitudes and aspirations (Barmby et al., 2008; Murphy & Beggs, 2003; Potvin & Hasni, 2014; Sheldrake et al., 2019; Speering, 1996). One of the earliest studies conducted in Australia was by Power (1981), who explored how students' attitudes towards science changed from primary to secondary schools in Australia. The results suggested that the transition did not affect students' attitudes towards science (Power, 1981). The majority of students enjoyed science at both levels, and there was no significant decrease found in student attitude as the year progressed. However, since this time, various international studies have reported that children enter secondary school with a positive attitude towards and an interest in science, but this decreases as they continue to experience and engage with high school science, particularly for girls (Barmby et al., 2008; Kahle & Lakes, 1983; Potvin & Hasni, 2014).

Speering's (1996) longitudinal study, which studied students' perceptions through their primary and then secondary years in Western Australia, explored students' perceptions about science. Students expressed that their experience of science in secondary school did not match their initial expectations of it. The study also showed that students' secondary school experience had long-term implications for their subject and career choices. Another recent longitudinal study (involving 2,258 Year 8 students across 88 secondary schools, and again in Year 10) explored students' changing attitudes and aspirations towards physics during secondary school (Sheldrake et al., 2019). The study indicated a decrease in students' interest in studying science, specifically physics, at Year 10. Interestingly, the students' intentions to study physics strongly correlated with their self-concept beliefs and intrinsic interest and enjoyment in physics. The authors of this study also found that a significant predictor to this was gender (Sheldrake et al., 2019). Overall, the results of this study showed that students' attitudes towards and beliefs about physics, and ultimately science, can change over time in positive ways.

Given that students' attitudes towards science can be cultivated, and that views of science are developed at an early age, the current study examined girls' views of science at primary and secondary school. The study builds on past research by exploring girls' attitudes towards science as they reach secondary school. Hence, the study fills a gap in the past research by providing insight into the contemporary context of secondary science classrooms in Australia.

2.4 Attitudes Towards Science

Since a major focus of the study reported in this thesis explores girls and science, in this section a review of literature related to attitudes towards science is provided. Section 2.4.1 defines attitude in the context of this study. Section 2.4.2 explores girls' attitudes towards science. Finally, Section 2.4.3 explores instruments used to assess attitudes towards science.

2.4.1 Definition of Attitude

The concept of *attitude* originated in the field of social psychology. This concept has been explained in different ways by different scholars. Thurstone (1928) defined attitude as being a person's "inclinations and feelings, prejudice or bias, preconceived ideas, notions, fears, threats, and convictions about any specific topic" (p. 531). Meanwhile, Allport (1935) defined an attitude as "a mental and neural state of readiness, organized through experience, exerting a directive and dynamic influence upon the individual's response to all objects and situations with which it is related" (p. 810). Further, Krech and Crutchfield (1948) wrote, "an attitude can be defined as an enduring organisation of motivational, emotional, perceptual, and cognitive processes with respect to some aspect of the individual's world" (p. 152). These definitions indicate the close link between attitude and behaviour and explain that attitudes are enduring.

Shrigley et al., (1988) extended this thinking by explaining that attitudes are learned in many ways and that the social influence of others plays a crucial role in this. The authors added that attitudes are learned from experience and can be taught. According to Shrigley et al., (1988), the most distinct attribute to the attitude definition is evaluation, that is, our preference to like or dislike something. Eagly and Chaiken (1993) defined attitude as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor" (p. 1). Although early definitions suggested that attitudes are enduring, more recent literature suggests that attitudes can be changed, and that context and social influence play a significant role in influencing a person's attitude towards something.

The term attitude can assume different meanings when used in discussions about science education, thereby rendering it a broad term. Therefore, it can be broken into two broad categories: "*attitudes towards science* (e.g., 'interest in science', 'attitudes towards scientists', 'attitudes towards social responsibility in science') and *scientific attitudes* (e.g., 'open-mindedness', 'honesty', 'scepticism')" (Gardner, 1975, p. 1). In this study, the focus was on *attitudes towards science*. Therefore, this study explored factors such as students' interest in science rather than their scientific attitudes.

2.4.2 Girls' Attitudes towards Science

This section explores past research that examined girls' attitudes towards science. Various studies point to sex differences in student attitudes to science (Cherian & Shumba, 2011; Kurt, 2016; Oon et al., 2020; Romine et al., 2017; Sofiani et al., 2017; Stoet & Geary, 2018). Prior studies suggests that student gender influences their general perceptions of science and their experience of science (Eccles, 2007; Kelly, 1987; Oakes, 1990). This section reviews the literature related to gender and attitudes, providing insights into how gender can influence a student's attitudes towards science, particularly regarding girls.

Although girls are more interested in school (Keeves & Kotte's, 1992) and have more positive perceptions of their relationship with their teacher (Eccles, 2007), past research has indicated that boys hold more favourable attitudes towards science (Fraser & Raaflaub, 2013; Weinburgh, 1995). Boys also report performing better than girls in school science (Ryan, 2016). In a study undertaken by Ryan (2016), results showed that boys in Year 8 were more likely to like, be confident about, be engaged in class and value science than were girls. Ryan (2016) also found that boys perform better in science in Year 8 than do girls. The overall findings suggested that boys like mathematics and science more, are more confident about their ability in these subjects and value both more than do girls. Geesa et al. (2020) explored the role of gender and attitudes towards science. The results of their study suggested that cultivating positive attitudes and fostering efficacy towards science could be a way to bridge the gender achievement and career choices gap in certain STEM areas.

Many studies have explored sex differences in attitudes towards science, particularly among secondary school students (Cherian & Shumba, 2011; Kurt, 2016; Oon et al., 2020; Romine et al., 2017; Sofiani et al., 2017; Stoet & Geary, 2018). Cherian and Shumba (2011) undertook a study in South Africa with 793 learners in Year 12 to explore sex differences in attitudes towards science. Kurt (2016) also explored differences between the sexes and their attitudes towards science with 157 middle school students attending private schools in the US. Both studies concluded that boys had more positive attitudes towards science than did girls (Cherian & Shumba, 2011; Kurt, 2016).

Similarly, Stoet and Geary (2018) used Program for International Student Assessment (PISA) results to explore gender in STEM education. Their study involving 72,242 15-to-16-year-old students from 67 nations or regions specifically considered sex differences in science attitudes, focusing on enjoyment of science, interest in science and self-efficacy. The authors found that boys had higher perceptions of self-belief and ability in science than did girls. Boys also articulated more interest in and enjoyment of science when compared with girls. Oon et al. (2020) also explored gender differences in attitude towards science with a sample of 495 boys and 490 girls from five secondary schools in Hong Kong. The authors found that girls' attitudes towards and interest in science, specifically physics, were less positive than boys. They also concluded that girls had less-positive attitudes towards science. All these studies focused on sex differences in attitudes towards science, and each sample included secondary school students. The studies found that sex was a significant factor in attitudes towards science and all concluded that boys had more positive attitudes towards science than did girls.

In contrast, other studies have found that girls do not differ from boys regarding their attitudes towards science. Sofiani et al. (2017) undertook a study exploring gender differences in attitudes towards science with 77 secondary school students from various schools in Bandung, Indonesia. Their study found no significant difference between boys and girls regarding attitudes towards science. Contrasting again, Hanson et al.'s (2020) study indicated significant gender differences. Boys reported more positive aspirations and attitudes towards science and less-stereotypical perceptions of scientists than girls. Cermik (2020) examined primary school students' attitudes towards science using a sample of 562 Year 4 students in the Denizli province in south-western Turkey. The author found no statistically significant sex differences concerning attitudes towards science. Further, Reddy (2017) explored gender differences in attitudes towards science with middle school students in South Africa and found no significant difference in attitude towards science between boys and girls.

Other research has reported varied results again, finding that girls have more positive attitudes towards science. Mihladiz et al. (2011) undertook a study with 882 Year 6, 7 and 8 students attending nine different schools in Turkey. The authors found that when investigating gender specifically, girls demonstrated higher attitude scores compared with boys.

Further to the studies listed above, past research has explored the role of gender stereotypes and their effect on sex differences in attitudes towards science. Gender stereotypes continue to be a major focus in research, with studies showing that of all the factors that may influence attitudes towards science, gender has consistently done so (Gugliotta, 2010; Schibeci, 1984). Studies have shown that girls, compared with boys, experience negative stereotypes about their abilities in science, which contributes to lower performance in tests and lower aspirations for STEM careers in the future (Hill et al., 2010).

Gender stereotypes influence attitudes towards science and contribute to gender differences regarding attitudes towards science. Gender stereotypes are most evident in mathematics and the sciences (Liu et al., 2010; Marsh, 1989). The stereotypical 'mad scientist' image of scientists has been recognised through several studies (Barman, 1997; Chambers, 1983; Narayan & Peker, 2009). Studies show that students still perceive scientists as male Caucasians wearing scientific safety equipment such as glasses and coats (Barman, 1997; Narayan & Peker, 2009; Todd & Zvoch, 2019). The study reported in this thesis builds upon this research, exploring students' perceptions of a scientist and unpacking how their perceptions influence their attitudes towards science, particularly regarding girls.

Past research has shown that many factors contribute to gender stereotypes, such as parental socialisation of gender roles (Breakwell & Beardsell, 1992), schools, textbooks and children's literature (Gugliotta, 2010). Research also indicates a male dominance in science (Archer et al., 2014), with many girls reporting that science is difficult and they are not motivation towards it in the same way as boys are (Fortus & Vedder-Weiss, 2014). Further, research has found that boys are more confident than girls in their academic abilities (Fredricks & Eccles, 2002; Ganley & Vasilyeva, 2011; Miller et al., 2006) particularly in relation to mathematics and the sciences (Marsh, 1989).

The study reported in this thesis builds upon this past research by exploring sex differences in attitudes towards science among students in different contexts. Further, it extends past research exploring the role of gender stereotypes and how they influence attitudes towards science, particularly for girls. Given there is limited research exploring sex differences in attitudes towards science among secondary school students in Australia, this study fills a gap in the research.

2.4.3 Instruments Developed to Assess Attitudes Towards Science

Many instruments have been developed to assess student's attitudes towards science. In this section, instruments measuring student attitudes towards science and instruments designed for primary and secondary school students are reviewed. Table 2.1 summarises these instruments, which comprise the Views of Nature of Science Questionnaire (Section 2.4.3.1), the Scientific Attitude Inventory (Section 2.4.3.2), Three-Dimensions of Student Attitude Towards Science (TDSAS; Section

2.4.3.3), the Women in Science Scale (WiSS; Section 2.4.3.4), the Attitude Toward Science in School Assessment (ATSSA; Section 2.4.3.5) and the Test of Science-Related Attitudes (Section 2.4.3.6).

Table 2.1 Overview of instruments used to assess attitudes towards science, level of education, dimensions and total number of scale items

Instrument	Reference	Level	Dimensions	Total Items
Views of Nature of Science Questionnaire	Abd-El-Khalick et al. (1998)	Secondary / higher education	Nature of science	10 open-ended questions
Scientific Attitude Inventory	Moore and Sutman (1970)	Secondary	12 position statements	5 attitude statements per position statement
Three-Dimensions of Student Attitude Towards Science	Zhang and Campbell (2011)	Primary	Student Affective Feeling About Science; Student Behavioural Tendencies in Learning Science; and Student Cognitive Judgement of Science Based on Their Values and Beliefs About Science	28 items
Women in Science Scale	Erb and Smith (1984)	Secondary	Characteristics Needed for Science Career Pursuit; Compatibility of Spouse, Parent, and Career Roles; and Equality of Opportunity to Pursue a Career	27 items
Attitude Towards Science in School Assessment	Germann (1988)	Primary/Secondary	Single Dimension of a General Attitude Towards Science	24 items
Test of Science-Related Attitudes	Fraser (1981)	Primary/Secondary	Social Implications of Science; Normality of Scientists; Attitude to Scientific Inquiry; Adoption of Scientific Attitudes; Enjoyment of Science Lessons; Leisure Interest in Science; and Career Interest in Science	70 items

The following sections provide a short description and review of the instruments identified in the table. This literature review was used to help select the instrument employed in this study and clarify why the instrument selected was the most suitable.

2.4.3.1 Views of Nature of Science Questionnaire

The Views of Nature of Science Questionnaire was developed by Lederman and O'Malley in 1990 and has been revised since (Abd-El-Khalick, 1998). It is an open-ended instrument that aims to provide meaningful assessments of the nature of learners' science views. The revised version (VNOS-Form C) comprises 10 open-ended questions. Examples of these questions are "What in your view, is science? What makes science different from other disciplines of inquiry?", "What is an experiment?", "Is there a difference between scientific theory and a scientific law? Illustrate your answer with an example".

The revised instrument has been used in several studies; however, establishing its validity is an ongoing process. The instrument has been used in various studies with pre-service secondary science and elementary teachers (Ağlarcı et al., 2016; Abd-El-Khalick & Lederman, 2000). Owing to the weaker psychometric evidence of this instrument and the nature of open-ended questions, it was not selected for this study.

2.4.3.2 Scientific Attitude Inventory

Moore and Sutman developed the Scientific Attitude Inventory in 1970 to measure scientific attitudes in secondary schools. The scale comprises 12 position statements. These position statements oppose each other and come in pairs (e.g., 1-A and 1-B). The statements are listed in pairs, in which the position statements labelled 'A' are positive attitudes related to science, and statements labelled 'B' are negative attitudes related to science. Some of these position statements include "The laws and/or theories of science are approximations of truth and are subject to change", "The basis of scientific explanation is an authority. Science deals with all problems, and it can provide correct answers to all questions" and "Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects". Five attitude statements were written for each position statement to measure whether students adopt the position.

The Scientific Attitude Inventory was field tested to demonstrate its construct validity (Moore & Sutman, 1970). Although the survey was reported to be valid in the 1970 study, it has not been used extensively. It is also a historical instrument that includes statements that are not relevant in the contemporary science classroom. Therefore, the survey was not selected for use in this study.

2.4.3.3 Three-Dimensions of Student Attitude towards Science

The revised Three-Dimensions of Student Attitude Towards Science (TDSAS) instrument was developed (Zhang & Campbell, 2011) and used to investigate elementary students' attitudes towards science. The TOSRA was used by Zhang and Campbell to help guide selection of the instrument's dimensions since they were based on the TOSRA's seven subscales.

The revised TDSAS comprises 28 items that fall under three key dimensions: Student Affective Feeling about Science, Student Behavioural Tendencies in Learning Science, and Student Cognitive Judgement of Science – based on students' values and beliefs about science. The TDSAS employs a Likert-type scale for all items, with the following five responses: strongly agree, agree, neutral, disagree and strongly disagree. Some of the sample items include "I think it is very important to learn science", "I always ask my parents science questions" and "I think people pay too much attention on science".

The TDSAS was included as part of a more extensive evaluation project undertaken in China to examine a new science learning program (Zhang & Campbell, 2011). The sample included 494 third-grade elementary students from 13 schools in Beijing, China. The whole instrument and three subscales evidenced acceptable internal consistency reliability and demonstrated appropriate concurrent validity in predictable ways. The Cronbach alpha for the three subscales ranged from .65 to .83. The factor loadings for all items were above.30, specifically they ranged between 0.30 and 0.70.

Although the evidence related to the psychometric properties supported the validity of the instrument, it was developed for use in a primary school setting. Since the study reported in this thesis involved secondary school students, this instrument was not deemed appropriate.

2.4.3.4 Women in Science Scale

Although the current study included boys as a comparison, its primary focus was girls. Therefore, it seemed pertinent to review literature related to this instrument. The Women in Science Scale (Erb & Smith, 1984) was developed to measure the attitude of early adolescent girls and boys towards women in science. Although it is an old instrument, it is still used today (Owen et al., 2007).

The WiSS comprises 27 items that fall under three key dimensions: Compatibility of Spouse, Parent and Career Roles; Characteristics Needed for Science Career Pursuit; and Equality of Opportunity to Pursue a Career. It has a six-point Likert scale ranging from strongly agree to strongly disagree, with no neutral point. The items are positively and negatively worded. Sample items include “Women can be as good in science careers as men can be”, “A husband’s success in his career is more important than a wife’s success in her career” and “A woman should have the same job opportunities in science careers as a man” (Erb & Smith, 1984. p. 393).

The WiSS has been used to assess an education program for early adolescents based on their science careers (Erb & Smith, 1984), and it guided the formation of the Early Childhood Women in Science Scale (ECWiSS). The ECWiSS is a modified version used to measure young children’s attitudes towards women in science (Mulkey, 1989). Past studies that have reported evidence to support the psychometric properties of the WiSS have used confirmatory factor analysis (for example, Owen et al., 2007). Owen et al. (2007) reported that a three-factor model was unsatisfactory, with X^2 (321) = 1975.5, $p<.001$. The data showed the CFI was .86 and the RMSEA was .06 (.90 CI = .059 – .064). Even more problematic were the inter-correlations between the three factors: .89, .90, and .90, suggesting redundancy among the claimed dimensions. Based on these problematic psychometric properties, this instrument was not selected for use in the current study.

2.4.3.5 Attitude Toward Science in School Assessment

The Attitude Toward Science in School Assessment (ATSSA) measures how students feel towards science as a subject in school. It comprises 34 Likert-type items, with the final revision comprising only 24 items. The items are presented as positive and negative statements, which are phrased and listed randomly in the instrument. Participants may choose from four responses: strongly agree, agree, disagree and strongly disagree. The scoring direction is reversed for the negatively phrased statements in the questionnaire. Three sample items are “Science is fun”, “I do not like science and it bothers me to have to study it” and “I would like to learn more about science”.

In his study, Germann (1988) found the ATSSA to be a valid and reliable instrument that supports sorting relationships between variables affecting attitude and achievement. However, its historical nature and its strong focus on assessment rendered it unsuitable for the current study.

2.4.3.6 Test of Science-Related Attitudes

The Test of Science-Related Attitudes (TOSRA), developed by Fraser (1981), assesses students’ attitudes towards science in the current study. The TOSRA was selected for this study because it has been used extensively and has been proven highly reliable in Australia and overseas (Fraser, 1981; Fraser, Aldridge, & Adolphe, 2010). The TOSRA is a favourable instrument because it allows the researcher to produce a separate score for several distinct attitudinal aims instead of a single overall score (Robinson & Fraser, 2013).

The TOSRA measures seven science-related attitudes relevant to secondary school students, these being Social Implications of Science (to assess the manifestation of favourable attitudes towards science); Normality of Scientists (to assess students’ attitude towards scientists as normal people rather than eccentrics); Attitude to Scientific Inquiry (to assess attitude towards scientific experimentation and inquiry as methods of obtaining information about the natural world); Adoption of Scientific Attitudes (to assess open-mindedness and willingness to reverse opinions related to scientific investigation and inquiry); Enjoyment of Science Lessons (to assess the enjoyment of science learning experiences); Leisure Interest in Science (to assess the development of interest in science and science-related activities); and Career Interest in Science (to assess students’ interest in pursuing a career in science).

The instrument comprises 70 items, with 10 items in each of the seven scales, half of which are negatively worded. Students respond to items of the TOSRA using a five-point Likert scale that provides responses of strongly agree, agree, not sure, disagree and strongly disagree to express their degree of agreement. Three sample items from the TOSRA include "Science lessons are fun" (from the Enjoyment of Science Lessons scale), "Finding out about new things is unimportant" (from the Adoption of Scientific Attitudes scale) and "I would like to be given a science book or a piece of scientific equipment as a present" (from the Leisure Interest in Science scale). The TOSRA was selected because it has been extensively field tested and shown to be highly reliable both in Australia (Fraser, Aldridge, & Adolphe, 2010; Kilgour, 2006; Lalor, 2006; Welch, 2010) and overseas (Fraser, 1981; Fraser, Aldridge, & Adolphe, 2010; Lowe, 2004; Tulloch, 2011).

2.5 Learning Environment Perceptions

A core focus of this study was girls' perception of the context in which their science learning takes place. To examine this important factor in science learning, the study drew on the field of learning environments. The field examines the psychosocial learning environment (as opposed to the physical or built environment). According to Fraser (1998b), the "learning environment refers to the social, psychological and pedagogical contexts in which learning occurs" (p. 3). The field of learning environments has experienced much change and development globally during the past 50 years (Fraser, 2012; Zandvliet & Fraser, 2019).

Moreover, extensive research has been conducted in the field of learning environments over the past 50 years (Dorman, 2002; Eccles, 2007; Fisher et al., 1997; Fraser, 2007; Goh & Khine, 2002; Lewin, 1952; Pace & Stern, 1958; Peer, 2011; Zandvliet & Fraser, 2019), with much of this research concentrating on the primary and secondary subject areas of mathematics and science (Skordi & Fraser, 2019). Therefore, this section reviews literature related to the field of learning environments relevant to the study reported in this thesis. Section 2.5.1 focuses on the history of the field of learning environments. Section 2.5.2 provides an overview of the research carried out in the field of learning environments pertinent to this study. Section 2.5.3 describes the development of learning environment instruments and the range of contemporary instruments used to measure classroom learning environment.

2.5.1 History of the Field

The field of learning environments draws on work conducted in the field of psychology. In the 1930s, Lewin (1952) recognised that the learning environment and interactions of individuals were powerful determinants of behaviour. Lewin's formula: B = *f* (E, P) stressed the need for new research strategies in which behaviour is a function of the person and the environment (Lewin, 1952; Fraser, 2007). In 1938, building on the work of Lewin, Murray classified a needs-press model of interaction highlighting personal needs and goals and how the environment can either support or hinder the expression of those needs.

Murray introduced the terms *alpha press*, which describes the environment perceived by a detached observer, and *beta press*, which describes the environment perceived by the occupants of a particular context or setting (Murray, 1938). Subsequently, in 1958, Pace and Stern developed Murray's model to differentiate between *private beta press* (the distinctive view of the environment by an individual) and *consensual beta press* (the shared view that members of a group hold about the environment). In classroom environment research, this has led to a common distinction between two units of analysis – the student and the class (Pace & Stern, 1958).

Classroom learning environment research specifically began about 50 years ago when the work of Walberg and Anderson (1968) and Moos (1974a) generated varied research foci globally (Aldridge & Fraser, 2008; Fisher & Khine, 2006,). The scholars began two independent programs: Walberg and Anderson (1968) developed learning environment instruments (LEI) as part of the Harvard Projects Physics curriculum, and Moos and Trickett (1974) developed the social climate scales, which resulted in the Classroom Environment Scale (CES). The CES was designed to gather data related to three key dimensions: Personal Growth, Relationships and Systems, and Maintenance and Change.

In his work related to social climates, which encompassed a range of settings (including prisons, hospitals and schools), Moos theorised that three dimensions as mentioned immediately above underpin all socially created environments, these being Personal Growth (assessing personal growth and self-enhancement), Relationships (the extent of involvement, support, nature and intensity regarding personal relationships of people involved in the learning environment) and Systems, Maintenance and Change (assessing "the extent to which the environment is orderly, clear in expectations, maintains control and is responsive to change"; Moos, 1979, p. 139). According to Moos (1979), the classroom environment can have a significant influence on a student's personal and academic development, and the social context of that environment is a major mediator. In the field of learning environments, instruments that are crafted seek to fulfil Moos's scheme so that data are gathered for each of the key dimensions.

This section has provided a brief overview of the history and development of research in the field of classroom learning environments. The next section reviews important instruments that have been developed over the years to aid in this research.

2.5.2 Review of Past Learning Environment Research

Extensive research has been conducted in the field of learning environments over the past 30 years (Zandvliet & Fraser, 2019), and considerable past classroom learning environment research has focused on varied levels of schooling and diverse subject areas, including mathematics and science (Skordi & Fraser, 2019). Reviews of classroom environment research by Fraser (1998a), Dorman (2002), and Goh and Khine (2002) highlighted key focus areas of classroom environment research, including learning environment and student outcomes; differences between students' and teachers' perceptions of the same classrooms; evaluation of educational innovations; comparing actual and preferred environments; effect on classroom environment of various variables (for example, gender, year level, school type, subject); teachers' practical attempts to improve their classroom climates; variations in classroom environment factors; cross-national studies; transition from primary to secondary school; and teacher education. In this section, a review of the literature related to the lines of research pertinent to the study reported in this thesis is provided, covering sex differences in learning environment perceptions (Section 2.5.2.1), differences between primary and secondary school (Section 2.5.2.2), and the relationship between perceptions of the learning environment and student outcomes (Section 2.5.2.3).

2.5.2.1 Sex Differences in Learning Environment Perceptions

One of the research questions in this study sought to understand whether differences exist between girls and boys enrolled in co-educational secondary schools in terms of their perceptions of the learning environment in science. Therefore, research related to sex differences in learning environment perceptions was explored. Past research suggests that girls and boys might perceive the learning environment differently (Eccles, 2007; Fisher et al., 1997; Fraser & Raaflaub, 2013; Li & Singh, 2021; Midgley et al., 1991; Peer, 2011).

Prior studies that explore sex differences in learning environment perceptions cover a vast range of settings. Much of this research has been undertaken with a focus on different subject areas, such as mathematics (e.g., Kombe et al., 2019; B. A. Taylor & Fraser, 2013) and physical education (e.g., Laxdal & Giske, 2020), and in tertiary environments (e.g., Khine et al., 2018). This research has spanned various countries, including Abu Dhabi (Aldridge & Rowntree, 2021), Myanmar (Khine et al., 2018), Saudi Arabia (Kim & Hamdan Alghamdi, 2019), Singapore (Peer, 2011) and the US (Kombe et al., 2019; B. A. Taylor & Fraser, 2013). Of interest to this study is past research that has examined differences in perceptions between girls and boys in science classrooms

Over the past 50 years, research has examined sex differences in the perceptions of students in science classes. The findings of these studies have provided mixed results. The majority of studies reported that girls hold a more favourable perception of the learning environment. Studies have reported these findings at different levels, including primary school (Peer, 2011), middle school (Boz et al., 2018) and tertiary education (Khine et al., 2018). Moreover, research has shown that girls with more positive learning environment perceptions also demonstrate higher levels of academic achievement (Eccles, 2007) and motivation (Aldridge & Rowntree, 2021). In contrast, some studies have reported that boys perceived their learning environment more positively compared with girls (Parvinder & Sarita, 2020). In some cases, studies have reported mixed results, with girls perceiving some scales more positively. For example, some studies have reported that girls perceive more task orientation and cooperation (Eccles, 2007; Khine et al., 2018; Peer, 2011), while other studies have found that boys perceive more involvement (Goh, 2014; Peer, 2011), teacher–student relations (Huang & Fraser, 2009) and student cohesiveness (Khine et al., 2018).

Researchers have argued that more research is needed to examine sex differences in science education, particularly given the current need to increase the desirability of science to girls (see, for example, Stoet & Geary, 2018). Further, researchers have highlighted the importance of naming and minimising gender biases in STEM to enable girls to have a more positive self-concept of STEM (e.g., Robnett, 2016). My study builds on and extends this past research not only by examining girls' perceptions of the learning environment in secondary settings but also by including qualitative information to provide causal explanations for girls' perceptions. Given the limited amount of current research available that has a distinct focus on gender differences in science learning environment perceptions in secondary schools in Australia, this study fills a gap.

2.5.2.2 Differences between Primary and Secondary School

In the primary school context, teachers' specialised STEM and science knowledge is minimal, which means they often lack confidence in teaching some of the content they are expected to teach. However, teachers typically have strong content knowledge in the secondary school context but do not have effective pedagogical strategies to represent the content in engaging and meaningful ways (MacDonald et al., 2020). Nurturing engagement in STEM and science education in primary school positively influences later participation in these disciplines, particularly in the senior secondary years (Rosicka, 2016).

Over the past 30 years, research has examined how the transition from primary to secondary school affects students (Fraser et al., 2012; Lofgran et al., 2015). This interest has grown over the last decade as further research at the point of transition has been undertaken (Coelho et al., 2020; Ng-Knight et al., 2019). One of the research questions in the study reported in this thesis sought to understand whether students' perceptions of the learning environment change from primary to secondary school. Therefore, research related to transition and differences between primary and secondary school was explored. This section examines the effects of transition on young adolescents, including systemic changes and achievement-related attitudes and learning environment perceptions.

For many adolescents, moving from primary school to secondary school is challenging (Deieso & Fraser, 2019; Jindal-Snape & Cantali, 2019; Moje, 2008). Research has shown that transition has a significant emotional and academic impact on students (Cox & Kennedy, 2008) and that many students find transition challenging (Ashton, 2008; Chedzoy & Burden, 2005; Coffey et al., 2011; van Rens et al., 2019).

Prior studies have demonstrated that students in secondary school have less-positive attitudes and classroom environment perceptions compared with primary school (Deieso & Fraser, 2019; Hine, 2001; Speering, 1996). Most students' transition from primary to secondary school involves a change from a generalist environment to a subject-specific focus. Studies have shown that the perception of secondary classroom environments was not as positive compared to primary school, and the varied lessons throughout the day and larger school sizes attributed to this (Ferguson, 1998; Hine, 2001). In some cases, the perceived learning environment deterioration was typically greater for girls than for boys (Ferguson, 1998). With the increase in specialised teachers in a secondary setting, teacher–student relationships were also perceived less favourably (Deieso & Fraser, 2019; Hine, 2001). The literature suggests that the varied and significant changes that occur in the classroom environment after the transition to high school contribute to a decline in achievement-related attitudes, values and behaviour (Midgley et al., 1989; van Rens et al., 2019).

Many researchers have conducted longitudinal studies across the primary–secondary transition years of schooling. All found that transition continues to be challenging for students at the onset of transition and over time (Coffey, 2013; Deieso & Fraser, 2019; Hine, 2001; Jindal-Snape & Cantali, 2019; West et al., 2010). The transition can cause a significant decline in science self-efficacy scores (Lofgran et al., 2015). Many studies highlight group transitions' ongoing and dynamic nature, with students experiencing problems and adapting at different times over their secondary years of schooling, particularly regarding the social-emotional aspect (Spernes, 2020; van Rens et al., 2019).

The past research discussed in this section informed the study reported in this thesis and influenced further exploration of this point of transition. This study delved deeper into the change in attitudes towards science and learning environment perceptions from primary to secondary school, providing a contemporary insight into the changes experienced in science. The thesis builds on past research by highlighting the various factors contributing to the attitude and perception changes from primary to secondary school levels. Moreover, it fills a gap in this field of research, exploring gender differences at the point of transition, with a particular focus on girls and science in co-educational and single-sex settings.

2.5.2.3 Learning Environment – Outcome Relationships

One of the research questions in this study sought to understand whether relationships exist between students' perceptions of their science classroom environment and their science achievement and attitudes. A common line of learning environment research is examining associations between students' learning outcomes and their perceptions of the classroom environment. This section reviews the past research that has examined environment–outcome relationships.

Research findings have suggested that the classroom learning environment affects students' cognitive and affective outcomes and therefore that establishing a suitable environment is important (Aldridge & Fraser, 2008; Rijken, 2017). Results of past studies have consistently found positive relationships between the learning environment and a range of outcomes (Adamski et al., 2013; Lee, 2010; Madu, 2010; Rucinski et al., 2018). Even when the setting is changed, significant correlations have been found between the learning environment and student outcomes (Cohn, 2011; Moss, 2003). These findings overwhelmingly suggest that the learning environment has a strong influence on students' cognitive and affective outcomes (Adedokun et al., 2017; Blau et al., 2018; Lamar et al., 2018; Pawlowska et al., 2014; Skordi, 2014).

Prior studies have specifically explored learning outcomes and achievement in science. This research found that "student's cognitive achievement and attitude toward science were enhanced when the learning environment was congruent with their learning environment preference" (Chang et al., 2011, p. 136) and when the classroom learning was continually improved (Brownson, 2006). Research has also shown positive relationships between student outcomes and the learning environment, as perceived by both students and parents (Allen, 2003).

Relationships between the learning environment and student attitudes have been studied. Scholars have found that learning environment scales are statistically significantly associated with attitude scales (Khalil & Aldridge, 2019; Peer, 2011; B. A. Taylor, 2004), showing that that more positive student attitudes are associated with more emphasis on the aspects of the learning environment. These studies confirmed that the nature of the classroom environment is related to students' attitudes towards science lessons. Relationships between the learning environment and student achievement have also been studied, finding that learning environment scales are statistically significantly associated with achievement (Cohn, 2011; Margianti, 2001; Rijken, 2017). These studies have shown that students' perceptions of the learning environment are positively linked to their achievement.

The current study builds upon this research by exploring correlations between science achievement and Australian secondary schools' seven learning environment scales. This study fills a gap in this research, providing insight into the Australian context and the relationships between outcomes and learning environments. It also provides an opportunity to understand better how the learning environment in Australian secondary science classrooms can be adapted to improve STEM outcomes for girls.

2.5.3 Learning Environment Instruments

A range of questionnaires have been developed in the field of learning environments. This section provides a short description and review of nine historical and contemporary instruments that have been widely used. This literature review was used to help select the instruments employed in this study and clarify why the instruments selected were most suitable. Table 2.2 summarises the nine classroom environment instruments, including the name of the instrument, the year level for which it is used, its items per scale and the dimension it falls under according to Moos's (1974b) scheme (e.g., relationship, personal development, and system maintenance and change dimensions). A review of each of the instruments displayed in the table is provided in the subsequent sections: Learning Environment Inventory (LVI; Section 2.5.3.1); Classroom Environment Scale (CES; Section 0); Individualised Classroom Environment Questionnaire (ICEQ; Section 2.5.3.3); My Class Inventory (MCI; Section 2.5.3.4); College and University Classroom Environment Inventory (CUCEI; Section 2.5.3.5); Questionnaire on Teacher Interaction (QTI; Section 2.5.3.6); Science Laboratory Environment Inventory (SLEI; Section 2.5.3.7); Constructivist Learning Environment Survey (CLES; Section 2.5.3.8); and the What Is Happening in This Class? Questionnaire (WIHIC; Section 2.5.3.9).

2.5.3.1 Learning Environment Inventory

Walberg and Anderson developed the Learning Environment Inventory (LEI) in 1968 (and it was later refined by Anderson et al. in 1982) to measure student perceptions of psychosocial aspects of the learning environment of science classrooms in a high school setting. The LEI is a 105-item survey, with items allocated to 15 scales of Cohesiveness, Apathy, Friction, Favouritism, Cliqueness, Satisfaction, Speed, Difficulty, Competitiveness, Diversity, Formality, Goal Direction, Disorganisation, Material Environment and Democracy. Participants respond to items using four responses: strongly agree, agree, disagree and strongly disagree. The scoring direction is reversed for the negatively phrased statements in the questionnaire. Three sample items are "A student has the chance to get to know all other students in the class" (from the Cohesiveness scale), "The class has rules to guide its activities" (from the Formality scale) and "The pace of the class is rushed" (from the Speed scale).

Table 2.2 Overview of level of education and number of items per scale, and classification of the scales according to Moos's scheme for nine classroom environment instruments

Instrument	Level	Items per Scale	**Scales Classified According to Moos's (1974b) Scheme**		
			Relationship Dimensions	Personal Development Dimensions	System Maintenance and Change Dimensions
Learning Environment Inventory (LEI)	Secondary	7	Cohesiveness Friction Favouritism Cliqueness Satisfaction Apathy	Speed Difficulty Competitiveness	Diversity Formality Material Environment Goal direction Disorganisation Democracy
Classroom Environment Scale (CES)	Secondary	10	Involvement Affiliation Teacher support	Task orientation Competition	Order & organisation Rule clarity Teacher control Innovation
Individualised Classroom Environment Questionnaire (ICEQ)	Secondary	10	Personalisation Participation	Independence Investigation	Differentiation
My Class Inventory (MCI)	Elementary	6–9	Cohesiveness Friction Satisfaction	Difficulty Competitiveness	
College and University Classroom Environment Inventory (CUCEI)	Higher Education	7	Personalisation Involvement Student cohesiveness Satisfaction	Task orientation	Innovation Individualisation
Questionnaire on Teacher Interaction (QTI)	Secondary/ Primary	8–10	Helpful/friendly Understanding Dissatisfied Admonishing Leadership Student responsibility and freedom Uncertain Strict		
Science Laboratory Environment Inventory (SLEI)	Upper Secondary/ Higher Education	7	Student cohesiveness	Open-endedness Integration	Rule clarity Material Environment
Constructivist Learning Environment Survey (CLES)	Secondary	7	Personal relevance Uncertainty	Critical voice Shared control	Student negotiation
What Is Happening In This Classroom? (WIHIC)	Secondary	8	Student cohesiveness Teacher support Cooperation	Investigation Task orientation Involvement	Equity

Note. Adapted from Fraser (2012), with permission (see Appendix 1).

The LEI has been used in various studies around the world that have assessed learning environments. The studies had several learning outcomes, including in relation to achievement (Walberg & Anderson, 1972), science attitudes (Haladyna et al., 1982; Hofstein et al., 1979) and perceptions (Lawrenz & Welch, 1983). Although the LEI is reported to be reliable (Haladyna et al., 1982; Hofstein et al., 1979; Lawrenz & Welch, 1983; Walberg & Anderson, 1972), the factor structure and the ability of each scale to differentiate between the perceptions of students in different classrooms have been found problematic (Fraser, 1998a).

Although scales from this survey have been adapted for use in some contemporary learning environment surveys, overall, the LEI is better suited to more traditional (rather than contemporary) classroom settings. Therefore, this survey was not considered suitable for use in the current study.

2.5.3.2 Classroom Environment Scale

The Classroom Environment Scale (CES), developed by Moos and Trickett (1974), examines the psychosocial environment of secondary school classrooms. It incorporates the intricate interactions that occur between teachers and students to explore their behaviour.

The CES has nine scales (Involvement, Affiliation, Teacher Support, Task Orientation, Competition, Order and Organisation, Rule Clarity, Teacher Control and Innovation) organised into three dimensions (Relationship, Personal Growth / Goal Orientation, and System Maintenance and Change). The CES contains 90 items that are responded to using a true–false response format. Three sample items are “Students in this class get to know each other really well” (from the Affiliation scale), “The teacher takes a personal interest in the students” (from the Teacher Support scale) and “Students put a lot of energy into what they do here” (from the Involvement scale). The CES has been used to measure the classroom environments in several studies, including measuring outcome measures such as academic achievement (Sigit et al., 2018), cognitive outcomes (Fraser & Fisher, 1982) and grades (Moos & Moos, 1978).

Although past research has reported the CES to be valid and reliable, it is problematic as, like the LEI, the CES is better suited to more traditional (rather than contemporary) classroom settings. Since the classroom environments examined in this study were more contemporary than those examined in the studies that had employed the CES previously, the CES was not considered for this study.

2.5.3.3 Individualised Classroom Environment Questionnaire

The Individualised Classroom Environment Questionnaire (ICEQ) was developed by Rentoul and Fraser (1979) explicitly to measure those learning environment dimensions that use inquiry-based and open-ended approaches to teaching and learning rather than traditional methods. The ICEQ has a short version and an extended version, as well as versions for teachers and students.

The ICEQ consists of 50 items, with 10 items measuring each of five scales: Personalisation, Participation, Independence, Investigation and Differentiation. Each item is scored on a five-point scale with responses of almost never, seldom, sometimes, often and very often (Rentoul & Fraser, 1979). Three sample items are "The teacher talks to each student" (from the Personalisation scale), "The teacher talks rather than listens" (from the Participation scale), and "Students choose their partners for groups" (from the Independence scale).

The ICEQ has been validated in Australia through a large study exploring individualised classroom learning environments (Fraser, 1981; Rentoul & Fraser, 1979) and several other studies conducted in Australia and Indonesia (Fraser & Fisher, 1986; Fraser et al., 1982). It has also been validated in England (Burden & Fraser, 1993).

Despite strong support for the reliability and validity of this survey, it was developed for use in inquiry-based classrooms. Given that the study reported in this thesis did not focus on inquiry-based learning, it was not considered a good fit for the research reported in this thesis.

2.5.3.4 *My Class Inventory*

The My Class Inventory (MCI) was developed by Fraser (1998a) to measure student perceptions of the learning environment in primary school settings (eight-to-twelve-years of age). The MCI was adapted from the LEI in three ways. First, the number of items and scales were reduced to 25 items in five scales (Cohesiveness, Friction, Satisfaction, Difficulty and Competitiveness). Second, the language was simplified to ensure suitability for use at the primary school level. Third, the MCI incorporated a two-point response format (Yes/No) to ensure easier responding for younger students. A sample item is “All pupils in my class are close friends” (from the Cohesiveness scale).

Studies have used the MCI to examine associations between the classroom learning environment and student outcomes (Melissa et al., 2015; Scott, 2006; Sink & Spencer, 2005). Although these studies provide evidence to support the reliability and validity of the MCI, there are several problems associated with it. First, the instrument includes a satisfaction scale as part of the learning environment; second, the factor structure of the MCI has not been supported; and third, the MCI uses a Yes/No format, which can suggest a right or wrong answer. Given the problems associated with this instrument and that it was developed for use with younger students in primary school settings, it was not considered appropriate for use in this study.

2.5.3.5 *College and University Classroom Environment Inventory*

The College and University Classroom Environment Inventory (CUCEI) was developed by Fraser and Treagust (1986) to measure student and teacher perceptions of learning environments at the tertiary level. The CUCEI assesses students’ or instructors’ perceptions of seven psychosocial dimensions of the actual or preferred classroom environment. The final form of the CUCEI has seven scales (Personalisation, Involvement, Student Cohesiveness, Satisfaction, Task Orientation, Innovation and Individualisation), each of which contains seven items. The items are responded to using a four-point format of strongly agree, agree, disagree and strongly disagree (Fraser & Treagust, 1986). The scoring direction is reversed for approximately half of the items. Two sample items are “The instructor goes out of his/her way to help me" (from the Personalisation scale) and "I make friends easily in this class" (from the Student Cohesiveness scale).

Various studies have used the CUCEI in several tertiary settings worldwide; however, in general, the original CUCEI has reported low reliability (Coll et al., 2002). Therefore, modified versions of the CUCEI were developed, and some studies showed it to be reliable (Nair & Fisher, 2001; Strayer, 2012). The CUCEI has explored various themes, including learning in an inverted classroom (Strayer, 2012) and, within the context of feminist pedagogy, understanding factors that influence classroom participation (Tedesco-Schnek, 2018). However, many studies have disputed its reliability. Logan et al. (2006) explored the modified CUCEI in two independent studies in computing classrooms in secondary schools and tertiary institutions in Wellington, New Zealand. The authors revealed several problems with the statistical performance of the CUCEI across both independent studies. Given that my study was carried out at the high school level, and this instrument is suited to students at the tertiary level, it was not considered appropriate for the current study.

2.5.3.6 Questionnaire on Teacher Interaction

The Questionnaire on Teacher Interaction (QTI) was first developed in the early 1980s in Dutch (Wubbels & Levy, 1993) to map students' and teachers' perceptions of interpersonal teacher behaviour. An American version was constructed in 1988 (Wubbels & Levy, 1991), which had 64 items, and then in 1993 an Australian version was created, which used 48 items (Den Brok, Fisher & Koul, 2005).

The QTI differs from other questionnaires that assess the classroom learning environment because it is the only questionnaire that explores the interpersonal relationship between teachers and their students (Quek et al., 2005; Watzlawick, Bavelas & Jackson, 1967). Although this instrument does not cover the dimension specified by Moos (1974b), it has been used widely in learning environment research, particularly in science classrooms (Fisher et al., 1995; Aldridge, Fraser & Soerjaningsih, 2010; Lee et al., 2003; Quek et al., 2005; Scott & Fisher, 2004).

The Australian version consists of 48 items, with six for every sector of the model of interpersonal teacher behaviour (Leadership, Helpful/Friendly, Understanding, Student Responsibility/Freedom, Uncertain, Dissatisfied, Admonishing and Strict). The American version of the QTI consists of 64 items that assess student perceptions of the same eight behaviour aspects. Each item is responded to using a five-point response scale ranging from never to always (Den Brok et al., 2004; Fraser, 2007; Schofield, 2013; Wubbels & Levy, 1993). Two sample items are, “She/he gets angry” (from the Admonishing behaviour scale) and “She/he gives us a lot of free time” (from the Student Responsibility/Freedom scale).

The QTI has been widely validated in various studies across the world. These interactions have spanned several focus areas, including chemistry classroom environments (Quek et al., 2005), high school science classrooms (Fisher et al., 1995; Lee et al., 2003), universities (Fraser, Aldridge, & Soerjaningsih, 2010) and international science studies (Fraser, Aldridge, & Soerjaningsih, 2010; Lee et al., 2003; Quek et al., 2005; Scott & Fisher, 2004).

The QTI was not selected for use in this study because the focus of this study was not solely on teacher behaviour and relationships but rather took a more holistic view of students’ perceptions of the learning environment. Although teacher behaviour influences students’ perceptions and attitudes, the QTI was considered too limiting.

2.5.3.7 Science Laboratory Environment Inventory

The Science Laboratory Environment Inventory (SLEI) was developed by Fraser et al. (1992, 1995) to assess the learning environment of science laboratories. In many high schools or higher education campuses, a science laboratory is often used when teaching science. Consequently, an instrument suited to assessing this environment was developed.

The SLEI has a total of 35 items, with five items in each of five scales (Student Cohesiveness, Open-endedness, Integration, Rule Clarity and Material Environment) It has a five-point response scale of almost always, often, sometimes, seldom and almost never. Two sample items are “Members of this laboratory class help me” (from the Student Cohesiveness scale) and “I decide the best way to proceed during laboratory experiments” (from the Open-Endedness scale).

The first version of the SLEI was used in a large cross-national study across Australia, Canada, England, Israel, Nigeria and the US. This study involved over 5,000 students (Fraser et al., 1992, 1993, 1995; Fraser & Griffiths, 1992; Fraser & Wilkinson, 1993). This was the first study to analyse the unique instructional setting of science laboratories. Following this study, a refined version of the SLEI evolved in which problematic items were removed from the instrument. Subsequently, several studies worldwide used this refined instrument to assess learning environments (Martin-Dunlop, 2004; McRobbie & Fraser, 1993).

Despite the strong evidence to support the reliability and validity of the SLEI across numerous countries, the specific focus of the survey on science laboratories rendered it unsuitable for use in the current study.

2.5.3.8 Constructivist Learning Environment Survey

P. C. Taylor et al. (1997) developed the Constructivist Learning Environment Survey (CLES) to measure the extent to which constructivist approaches are being adopted in the classroom. The CLES has 30 items, with six items in each of five scales (Personal Relevance, Uncertainty, Critical Voice, Shared Control and Student Negotiation). The CLES was the first instrument to arrange items consecutively rather than randomly or cyclically (B. A. Fraser, 2007). A sample item is “In this class, I learn about the world outside of school” (from the Personal Relevance scale). In 2000, the original CLES was expanded by Wilks (2000) to include two new scales: Political Awareness and Ethic of Care. The response scale ranges from almost never to almost always.

The CLES has been used and validated widely in many studies around the world, including Korea (Lee & Taylor, 2001), Taiwan (Aldridge et al., 2000) and Minnesota (Johnson & McClure, 2004), exploring a range of classroom environments that adopted constructivist-oriented teaching strategies. The CLES was not used in the current study because the primary focus was not on adopting constructivist approaches but rather on classroom learning environment perceptions.

2.5.3.9 What Is Happening in This Class? Questionnaire

The What Is Happening in This Class? (WIHIC) questionnaire was developed by Fraser, Fisher and McRobbie (1996) to combine important scales from past questionnaires with contemporary educational dimensions. The WIHIC questionnaire combines scales from a range of existing questionnaires but has been modified to include new scales related to contemporary education. These are Equity and Constructivism. The final version of the WIHIC contains 56 items, with eight items in each of seven scales (Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation and Equity). Table 2.2 describes these scales and items. The WIHIC includes five possible responses (almost never, seldom, sometimes, often and almost always)

The WIHIC has been found valid and reliable when used in several countries (Dorman, 2003) and with various subject areas (Aldridge & Fraser, 2000; Aldridge et al., 2006; Margianti et al., 2001; Zandvliet & Fraser, 2005). These studies used various samples, including secondary school students (Aldridge et al., 1999; Dorman, 2003), pre-service teachers (Martin-Dunlop, 2013) and kindergarten students and their parents (Robinson & Fraser, 2013).

The WIHIC questionnaire has been proven the most contemporary and reliable instrument employed in a range of studies around the world with varied contexts to measure classroom environments (Alt, 2018; Charalampous & Kokkinos, 2017; Deieso & Fraser, 2019; Giles, 2019; Khalil & Aldridge, 2019; Khine et al., 2018; Lim & Fraser, 2018; Long et al., 2019; Skordi & Fraser, 2019; Zaragoza & Fraser, 2017). Because the WIHIC is the most frequently used classroom environment questionnaire today, it was selected as the instrument for my study.

2.6 Chapter Summary

This chapter reviewed the literature related to girls and science, science for girls in different settings, attitudes towards science and learning environment perceptions. First, Section 2.2 reviewed the literature related to girls and science. It started by reviewing research related to current trends in science and STEM. Much past research confirms the decline in interest and engagement of girls in STEM and science (Kinskey, 2020) and the under-representation of women in STEM fields (Australian Government, 2017; Campanini, 2020). The literature review indicated that girls and women are less involved compared to men and boys in many areas of science and that their aspirations for science-related careers is declining. It then reviewed the literature related to achieving equitable science outcomes for girls, highlighting that STEM-related careers are mainly male oriented (Holmes et al., 2017) and that students' science achievements are positively associated with STEM career aspirations (Cairns & Dickson, 2021). It also highlighted differing research showing that encouraging girls into science can improve their attitudes but not their career choices (Darke et al., 2002). Further, research was reviewed that showed that teachers attribute girl's high achievement in science to their plodding diligence and boy's achievement to their raw talent (Carlone, 2004), which highlights unequitable outcomes for girls.

Section 2.3 reviewed the literature related to science for girls in different settings. First, Section 2.3.1 reviewed literature related to single-sex versus co-educational settings. Studies found that single-sex settings positively influenced girls' behaviours and abilities in science (Belfi et al., 2012; Sikora, 2014) and their career aspirations and achievement (Koniewski & Hawrot, 2021; Monaco & Gaier, 1992). Research also found that girls in single-sex classrooms felt more socially accepted and experienced a higher sense of belonging (Belfi et al., 2012). In contrast, other studies found little or no difference between the two settings (Pahlke et al., 2014) and that single-sex settings can harm future opportunities for young women in education and their future career choices (Koniewski & Hawrot, 2021).

Following this, Section 2.3.2 reviewed literature related to science for girls in primary and secondary settings. It highlighted that young people, particularly girls, continue to display diminished interest and achievement in science and STEM fields (Kinskey, 2020) and are rapidly losing their interest in these science-related careers as they progress towards the end of middle school (Potvin & Hasni, 2014). Studies also showed that students' interest in and attitude towards science declines when students start secondary school (DeWitt et al., 2013) with the most significant decline happening for girls (Burns et al., 2016).

Section 2.4 explored a major part of the study which was girls' attitudes towards science. Section 2.4.1 defined attitude in the context of this study, stating that the term is a broad one and, even when it is used in discussions about science education, can take on different meanings. This section explained that the focus for this study was on attitudes towards science, and it explored factors such as students' interest in science rather than their scientific attitudes. Research related to girls' attitudes towards science was reviewed in Section 2.4.2. Past research has shown that student gender influences perceptions of science experiences generally (Eccles, 2007; Kelly, 1987; Oakes, 1990). The research highlighted boys continue to hold more favourable attitudes towards science (Cherian & Shumba, 2011; Fraser & Raaflaub, 2013; Kurt, 2016; Weinburgh, 1995) and perform better than girls in school science (Ryan, 2016). Conversely, research has shown that there are minimal sex differences regarding students attitudes towards science (Cermik, 2020; Reddy, 2017; Sofiani et al., 2017); it has also shown that girls have more positive attitudes towards science (Mihladiz et al., 2011). Lastly, Section 2.4.2 highlighted that gender stereotypes play a significant role in attitudes, with gender stereotypes being most evident in mathematics and the sciences (Liu et al., 2010; Marsh, 1989). Research shows a male dominance in science (Archer et al., 2014), with many girls reporting that science is difficult and that they do not have as much motivation towards it compared with boys (Fortus & Vedder-Weiss, 2014).

Following this, Section 2.4.3 reviewed instruments used to assess attitudes towards science that were most relevant to this study. These instruments included the Views of the Nature of Science Questionnaire; the Scientific Attitude Inventory; the TDSAS; the WiSS; and the ATSSA. This included the TOSRA, the quantitative instrument used in the present study.

Section 2.5 reviewed learning environment perceptions and research related to the field of learning environments. Section 2.5.1 highlighted the history of learning environments sharing how learning environment research originated in 1930 through Lewin (1936) and Murray (1938) and how other researchers in the field of learning environments, such as Walberg and Moos (1974b), played a significant role. Section 2.5.2 then reviewed literature related to the field of learning environments relevant to the study. It highlighted research showing that student gender influences learning environment perceptions (Eccles, 2007; Fisher et al., 1997; Fraser & Raaflaub, 2013; Li & Singh, 2021; Midgley et al., 1991; Peer, 2011), with many female students generally holding a more favourable perception of the learning environment (Den Brok et al., 2006; Fraser & Raaflaub, 2013; Lim, 1995). It reviewed literature relating to transition from primary to secondary school finding that, for many adolescents, moving from primary school into secondary school is challenging (Deieso & Fraser, 2019; Jindal-Snape & Cantali, 2019; Moje, 2008) and students in secondary school have less-positive attitudes and classroom environment perceptions compared with their primary school experience (Deieso & Fraser, 2019; Hine, 2001; Speering, 1996). It also reviewed literature related to learning environment and outcome relationships, highlighting research that found positive relationships between the learning environment and a range of outcomes (Adamski et al., 2013; Lee, 2010; Madu, 2010; Rucinski et al., 2018). This research overwhelmingly suggested that the learning environment has a strong influence on students' cognitive and affective outcomes (Adedokun et al., 2017; Blau et al., 2018; Lamar et al., 2018; Pawlowska et al., 2014; Skordi, 2014).

Lastly, Section 2.5.3 reviewed historically important and contemporary classroom learning environment instruments and questionaries that have been developed and widely used in this field of learning environment research. These instruments included the LEI; the CES; the ICEQ; the MCI; the CUCEI; the QTI; the SLEI; the CLES; and the WIHIC, the quantitative instrument used in my study.

The methodology used to collect, analyse and interpret data for this study is discussed in the next chapter.

Chapter 3

RESEARCH METHODS

3.1 Introduction

Whereas the previous chapter reviewed the literature pertinent to the study reported in this thesis, Chapter 3 describes and justifies the research methods used to answer the six research questions. In this chapter, there are eight sections, each describing a different aspect of the research methods.

- Author Positionality (Section 3.2)
- Research Questions (Section 3.3)
- Research Design (Section 3.4)
- Sample (Section 3.5)
- Data Collection Methods (Section 3.6)
- Data Analysis (Section 3.7)
- Ethical Considerations (Section 3.8)
- Chapter Summary (Section 3.9).

3.2 Author Positionality

Positionality refers to the researcher's position that they adopt and its subsequent political and social context along with their worldview. Holmes (2020, p. 1) sums this up:

> The individual's world view or 'where the researcher is coming from' concerns ontological assumptions (an individual's beliefs about the nature of social reality and what is knowable about the world), epistemological assumptions (an individual's beliefs about the nature of knowledge) and assumptions about human nature and agency (individual's assumptions about the way we interact with our environment and relate to it). These are coloured by an individual's values and beliefs that are shaped by their political allegiance, religious faith,

> gender, sexuality, historical and geographical location, ethnicity, race, social class and status, abilities and so on. (Holmes, 2020, p. 1)

Given that my research involved a mixed-methods approach, which included collecting qualitative data, it was meaningful to disclose my positionality to acknowledge my views, values, and beliefs.

At the time of writing this thesis, I was 35 years old. I am a white Caucasian female, born and bought up in metropolitan South Australia. The primary and secondary schools I attended were private Catholic schools located in high socio-economic areas. During my middle school years (aged 11 to 14), I attended a single-sex all-girls school, and in my secondary school years (aged 15 to 17), I attended a coeducation secondary school.

During my primary school years, I do not recall learning science or being involved in science-related activities (such as experiments or investigations). My first memory of learning science was in year 6, when I attended middle school. During my middle school years, my confidence in science grew, and I developed a keen interest in the subject in this single-sex setting. When I moved to secondary school, a co-educational setting, my confidence in my ability to learn science declined.

My studies included a Bachelor of Science and Bachelor of Education during my undergraduate years. While at university, my passion and confidence in the sciences grew again, especially as I could choose a major and minor subject that was of interest to me. After graduating, my first teaching position was as a specialist science teacher in a co-education primary school. Following this, I was a specialist mathematics and science teacher in a single-sex all-girls middle school.

As a specialist mathematics and science teacher, I taught students who had just started their secondary schooling and was privy to varied narratives about students' experiences in primary school science. My experiences working with diverse students from a range of primary schools at their entry point to secondary school ultimately led to my interest in carrying out research to learn more about the experiences of girls and science.

Throughout the study I took a reflexive approach employing ongoing self-reflection to enable me to identify, construct, critique, and articulate my positionality. Engaging in a reflexive approach allowed me to reduce bias and partisanship (as recommended by Rowe, 2014). In this respect, reflexivity allowed "… a self-scrutiny on the part of the researcher; a self-conscious awareness of the relationship between the researcher and another" (Bourke, 2014, p. 2). Acknowledging my positionality inside this educational context helped to clarify my theoretical lens.

3.3 Research Questions

The six research questions used in this study, introduced in Chapter 1, are reiterated here.

Research Question 1

Are the instruments used to assess students' attitudes towards science and their perceptions of the learning environment valid and reliable when used with secondary school students in South Australia?

Research Question 2

What attitudes do girls' hold towards science, and how do they perceive the learning environment in secondary science classes?

Research Question 3

Do differences exist between girls in co-educational and single-sex schools in terms of their attitudes towards science and learning environment perceptions?

Research Question 4

Do girls' attitudes and their perceptions of the learning environment differ between primary and secondary school settings?

Research Question 5

Do differences exist between girls and boys in secondary school in terms of their attitudes towards secondary school science classes and their perceptions of the learning environment?

Research Question 6

Do relationships exist between girls' perceptions of their science classroom environment and their:

- attitudes towards science and
- science achievement?

3.4 Research Design

This section details the research paradigm applied to this study (Section 3.3.1). It then explores the mixed methods nature of the study (Section 3.3.2) and describes the explanatory sequential design used (Section 3.3.3)

3.4.1 Research Paradigm

The research paradigm of a study is fundamental because it informs the research design. Shannon-Baker (2016) argued that it is essential to discuss which paradigmatic approaches relate to mixed methods in general. A range of paradigms may be used in research, including positivism, interpretivism, critical realism and critical theory (Johannesson & Perjons, 2014).

The study's design was informed by interpretivism (see Chapter 1 for further information about how the interpretivist paradigm was used to inform the study).Interpretivists prefer to use qualitative methods because they provide better opportunities to understand how people interpret the world around them (Willis, Jost & Nilakanta, 2007). However, both quantitative and qualitative methods are compatible with interpretative research (Willis, Jost & Nilakanta, 2007). I used the interpretivist stance when approaching data collection, analysis, and interpretation since I aimed to make localised meaning through the participants' experiences. For this study, the interpretivist stance meant that the overarching focus was on the *students' experiences*. With this overarching focus in mind, a mixed-method approach involving the collection qualitative and quantitative data was selected and used in this study, which employed an explanatory sequential design, described in Section 3.3.3.

3.4.2 Mixed Methods Design

The study reported in this thesis utilised a mixed methods approach that combined quantitative and qualitative methods to explore the research questions. Past research has indicated that combining qualitative and quantitative research methods is beneficial (Creswell, 2008; Plano Clark, 2017) because it offers richer insights and captures information that might be missed if only one data collection method is used (Caruth, 2013). Further, different research methods complement each other and result in more questions of interest for future studies. The strengths of using a mixed methods design include a more comprehensive range of research questions, a more robust conclusion and enhanced validity through triangulation (Cronholm & Hjalmarsson, 2011). Greene (2015) stated that:

> a mixed methods perspective legitimizes multiple ways of seeing and hearing, multiple ways of making sense of the social world, and multiple standpoints on what is important and to be valued and cherished. A mixed methods perspective recognizes that each methodological standpoint is inevitably partial. Any single approach necessarily offers but one window on human phenomena. So, multiple approaches – each legitimized, each valued, and each positioned at a different angle – can offer a more complete and fuller understanding of the human endeavors being studied. (p. 750)

Whereas early research related to students' attitudes and classroom learning environments has predominantly used quantitative methods, more recent research, which combines quantitative and qualitative methods, has been a distinctive thrust of current research within the field of learning environments (Aldridge et al., 1999; Kagumba, 2015; Martin-Dunlop, 2013; Sirrakos & Fraser, 2017). These studies have found that gathering qualitative data through focused classroom observations and interviews provides a means of uncovering rich, contextual understandings of learning environments. This study sought to provide a rich, contextual understanding of students experiences of the learning environments by combining quantitative and qualitative data.

3.4.3 Explanatory Sequential Design

Different mixed methods designs may be utilised, including the concurrent triangulation approach, the concurrent embedded strategy, the concurrent transformative approach, the sequential transformative strategy, and the explanatory sequential design (Creswell & Plano Clark, 2011). Each design has a unique approach and gives varied weights to the qualitative and quantitative data. In this study, an explanatory sequential design was considered the most suitable to address the research questions and is described below.

As pictured in Figure 3.1, the mixed methods explanatory sequential design consists of two distinct phases: the collection of quantitative data followed by qualitative data (Creswell et al., 2003). In this study, a follow-up explanations model was used. In this model, quantitative findings that required further explanation were identified through qualitative data collection (Creswell, 2008).

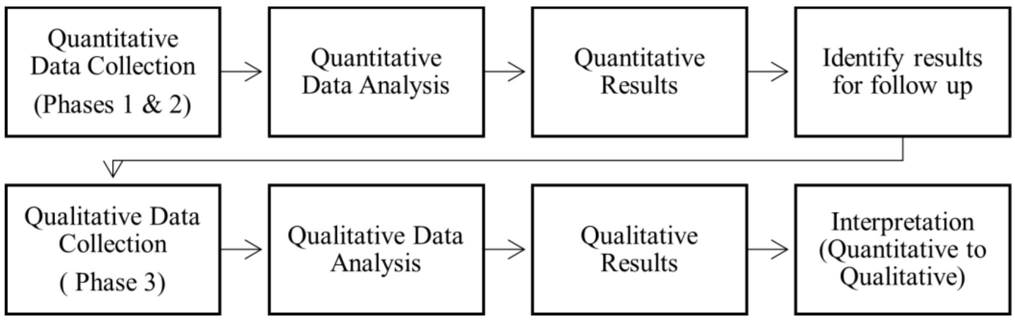

Figure 3.1 Explanatory sequential design: Follow-up explanations model

Note. Adapted from Creswell (2008, p. 73).

In this design, quantitative data were collected and analysed at two points in time (Phases 1 and 2). The first phase involved administering surveys to Year 8 students in their first month of starting secondary school (to provide a retrospective view of their perceptions of their primary school science classrooms). The second phase involved the administration of the same surveys to the same students eight months into the academic year (to provide a view of their perceptions of their secondary school science classrooms). Following the quantitative data collection, qualitative data were collected and analysed to help explain or elaborate on the quantitative results (Phase 3). The emerging quantitative results guided the collection of qualitative data, and the analysis explained or elaborated on the quantitative results to provide more depth (Creswell, 2003; Rossman & Wilson, 1985)

3.5 Sample

The following section explains how the sample for the present study was selected. It first describes the selection of schools (Section 3.4.1), followed by the selection of students for the quantitative data collection (Section 3.4.2), and finally, the selection of students for the qualitative data collection (Section 3.4.3).

3.5.1 Selection of Schools

As a first step, it was important to identify a sample space that was able to capture girls' secondary school science experiences in South Australia. The study employed a probability sampling approach (Creswell, 2008) in which the researcher selected individuals from the population who were representative of that population. This strategy was selected because it is one of the most rigorous forms of sampling employed in quantitative research. Using this method, I was better able to claim that the sample was representative of the population and therefore make generalisations to the population (Creswell, 2008). The sample space for the study was defined as students from science classes in Year 8 from a range of secondary schools in South Australia. Hence, the sample was drawn from 10 secondary schools in South Australia. This section describes the criteria used to guide the selection of schools from which the sample was drawn.

First, to ensure a degree of comparability across the sample, the selection of the schools was made to ensure that the student population for each had a similar socio-economic status. The Index of Community Socio-Educational Advantage (ICSEA) value was used to indicate the relative socio-economic status of each school. The ICSEA was created by the ACARA and is a scale that allows for fair and reasonable comparisons among schools with similar students. The criterion used for school selection was that schools must have an ICSEA value within 100 points of the average ICSEA value of 1,000. In all cases, the selected schools fell within 83 points of the average ICSEA value.

Second, to increase the generalisability of the results and provide a suitable sample to answer research questions 2 to 6, the selection of the 10 schools involved a mix of both single-sex all-girls (n = 2 schools) and co-educational schools (n = 8 schools).

Third, to increase the generalisability of the results further, schools were selected from both regional South Australia (n = 3 co-educational schools) and metropolitan South Australia (n = 7), with two schools being single-sex all-girls and five schools being co-educational.

To summarise, the population was stratified using specific characteristics, as recommended by Cohen et al. (2000) and Creswell (2008) to ensure that the schools:

- represented both public and private schools
- were located both regionally and within metropolitan Adelaide
- had a similar socio-economic status
- included a mixture of both co-educational and single-sex all-girls schools.

Figure 3.2 provides a summary of the various sampling methods employed at different stages of the study.

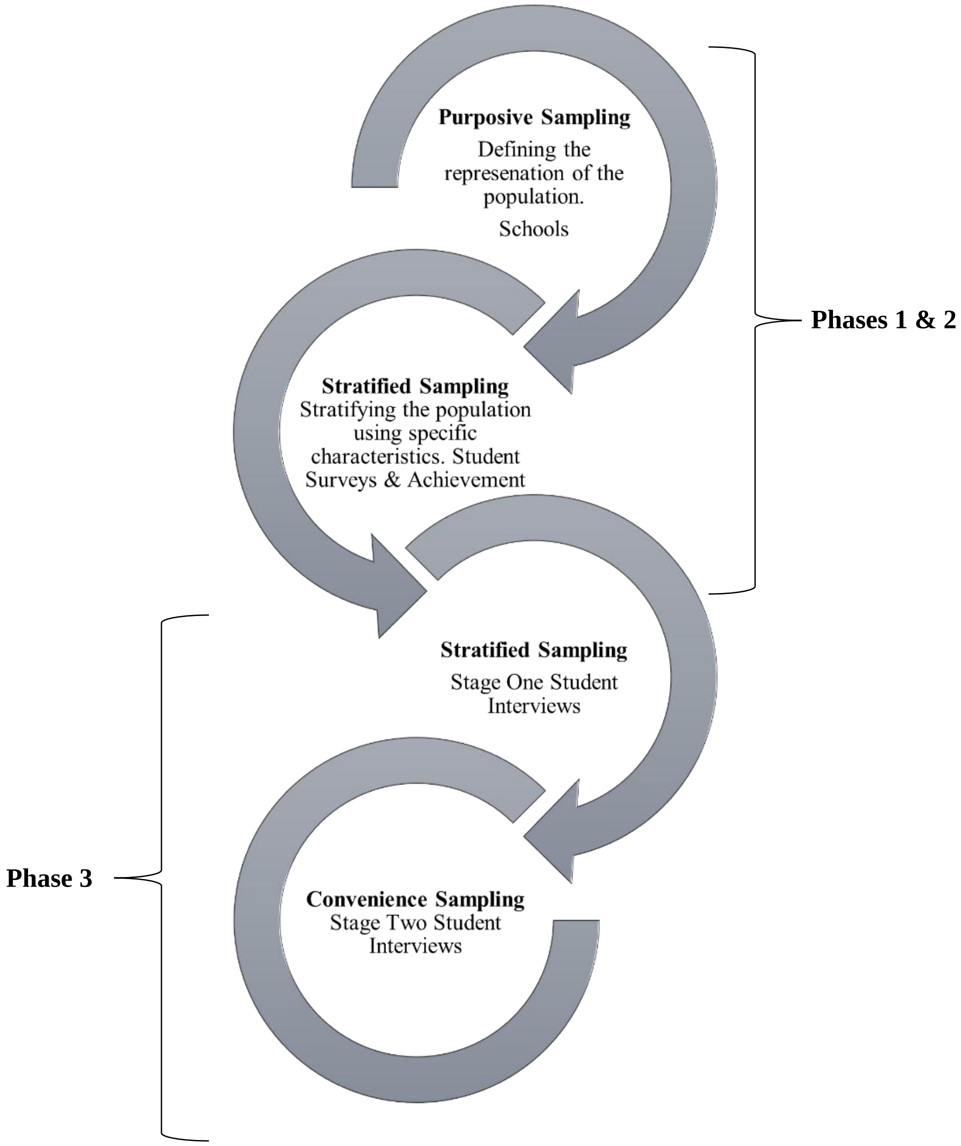

Figure 3.2 Summary of the sampling methods employed at different stages of the study

3.5.2 Sample for the Quantitative Data Collection (Phases 1 and 2)

The sample was used for the TOSRA and WIHIC data collection and involved students from 12 Year 8 science classes – nine classes in co-educational schools and three classes in single-sex all-girls schools. The classes in co-educational schools provided a sample of 149 students – 74 boys and 75 girls. This sample represented the broader school population. According to the Australian Bureau of Statistics (2018), 408 (48%) full-time Year 8 girls and 444 (52%) full-time male Year 8 students were enrolled in South Australian Schools in 2018. In addition to the nine classes selected from co-educational schools, three were selected from two single-sex all-girls schools. Owing to this additional data, the complete sample involved a higher proportion of girls than represented in the wider population. The three classes drawn from all-girls single-sex schools provided a sample of 55 girls. Table 3.1 summarises the breakdown of classes and students in the different types (co-educational and single-sex) of schools. Three regional schools were represented for generalisability (providing a sample of 35 students) and seven metropolitan schools were represented (providing a sample of 169 students).

The sample used to examine environment–achievement relationships was based largely on the response of teachers to a request for achievement data. Teachers from seven of the 10 schools provided achievement data. Of these schools, two were single-sex (55 students) and five were co-educational (69 students). Three of these schools were regional and four were from metropolitan Adelaide. This provided a sample of 89 girls.

Table 3.1 Summary of students included in the sample

	Number of Schools	Number of Classes	Number of Students					
			Pre-test	Post-test	Regional	Metropolitan	Boys	Girls
Co-educational schools	8	9	149	149	35	114	74	75
Single-sex schools – girls	2	3	55	55	0	55	0	55
Total	10	12	204	204	35	169	74	130

The selection of this sample was purposeful, insofar as different samples were required to answer different research questions. Summarised below (Table 3.2) are details of the samples used to address each research question.

Table 3.2 Samples used to address each research question

Research Question	Phase	Boys	Girls	Unidentified Sex	School Type	Sample	Total
1. Are the instruments used to assess students' attitudes towards science and their perceptions of the learning environment valid and reliable when used with secondary school students in South Australia?	Phase 1	96	161	12	Co-educational Single-sex girls	209 60	269
	Phase 2	77	128	18	Co-education Single-sex girls	150 55	223
2. What attitudes do girls' hold towards science, and how do they perceive the learning environment in secondary science classes?	Phase 1	—	—	—	—		—
	Phase 2	—	130	—	Co-educational Single-sex girls	75 55	130
3. Do differences exist for girls in co-educational and single-sex schools in terms of their attitudes towards science and their learning environment perceptions?	Phase 1	—	—	—	—		—
	Phase 2	—	130	—	Co-educational Single-sex girls	75 55	130
4. Do girls' perceptions of the learning environment and their attitudes differ between primary and secondary school settings?	Phase 1	—	130	—	 Co-educational	75 55	130
	Phase 2	—	130	—	Single-sex girls	75 55	130
5. Do differences exist between girls and boys in secondary school in terms of their attitudes towards secondary school science classes and their perceptions of the learning environment?	Phase 1	—	—	—	—		—
	Phase 2	74	75	—	Co-educational	149	149
6. a) Do relationships exist between girls' perceptions of their science classroom environment and their attitudes towards science	Phase 1	—	—	—	—		—
	Phase 2	—	130	—	Co-educational Single-sex girls	75 55	130
6. b) Do relationships exist between girls' perceptions of their science classroom environment and their science achievement?	Phase 1	—	—	—	—		—
	Phase 2	—	89	—	Co-educational Single-sex girls	34 55	89

3.5.3 Sample for Qualitative Data Collection (Phase 3)

In addition to the large-scale sample collected at Phases 1 and 2, qualitative information was collected at Phase 3. This sampling followed Phase 1 and Phase 2, when it became evident that new information was needed to provide deeper insights into the quantitative data to help to answer the research questions. The collection of qualitative data occurred in two stages, referred to as Stage 1 and Stage 2. Section 3.4.3.1 reports the selection of and sample for Stage 1, and Section 3.4.3.2 reports the sampling method and sample used for Stage 2.

3.5.3.1 Stage 1 of Phase 3: Collection of Qualitative Information

The sampling procedure for Stage 1 of Phase 3 was purposeful, since select students were chosen who could best help the researcher to understand the research problem (Creswell, 2008). As with Phase 1 and 2, stratified sampling – as described by Cohen et al. (2000) and Creswell (2008) – was used to stratify the sample. The following criteria were used to stratify the sample selection:

- An evenly balanced mix of boys and girls was required from co-educational schools (n = 10 boys, n = 10 girls).
- Girls came from both co-educational classrooms (n = 5 schools) and single-sex classrooms (n = 2 schools).
- All students came from a Year 8 science classroom.
- Students had varying levels of ability.

Purposive sampling was then used to select suitable students. At this stage, teachers assisted with selecting students based on their level of achievement (providing approximately one low achiever, one medium achiever and one high achiever from each school). The researcher defined specific characteristics before selecting this sample to ensure that it was representative of the target population and relevant for the various research questions.

The sample for the qualitative data collection was drawn from 6 of the 10 schools. The sample involved 26 students – 10 boys from a co-educational setting and 16 girls, 10 of whom were from a co-educational setting and 6 from a single-sex setting.

3.5.3.2 Stage Two of Phase 3: Collection of Qualitative Information

In keeping with the interpretivist paradigm, which allows for emerging themes, the need for further analysis was identified. After analysis of the quantitative (Phase 1 and 2) and qualitative data (Phase 3: Stage 1), it was decided that further interviews were required to ensure that the information was correct, particularly concerning differences between girls in a co-educational setting and those in a single-sex setting. The final sample for this stage was influenced by saturation. Data saturation is gained through a continual data sampling until no new information is obtained (Bowen, 2008).

The selection of the sample at this stage involved convenience sampling (Creswell, 2008). The sample was all girls, drawn from two schools, one co-educational and one single-sex. Sixteen girls were interviewed, three from the co-educational school and 13 from the single-sex school. Both groups had similar socio-economic statuses and were from metropolitan Adelaide. Again, teachers helped to select students based on their level of achievement. As a result, interviews were held with one low achiever, one medium achiever and one high achiever at the co-educational school, and four low achievers, five medium achievers and four high achievers at the single-sex school.

Saturation occurred at the end of Stage 2, with a total of 19 girls from a single-sex setting, 13 girls from a co-educational setting and 10 boys from a co-educational setting. These numbers (for saturation) included both Stage 1 and Stage 2 interviews.

3.6 Data Collection Methods

This section describes the instruments used to collect data at the different phases of the study. First, the surveys used to collect quantitative data are described: the TOSRA (Section 3.5.1) and the WIHIC (Section 3.5.2). Then, the semi-structured interviews used to collect qualitative data are described (Section 3.5.3). Lastly, Section 3.5.4 describes the data collected to measure achievement.

3.6.1 Test of Science-Related Attitudes

The TOSRA, developed by Fraser (1981), was used in this study to assess students' attitudes towards science. The TOSRA was selected because it has been extensively field tested and shown to be highly reliable both in Australia (Fraser, Aldridge, & Adolphe, 2010; Kilgour, 2006; Lalor, 2006; Welch, 2010) and overseas (Fraser, 1981; Fraser, Aldridge, & Adolphe, 2010; Lowe, 2004; Tulloch, 2011). See Chapter 2 for more detail related to these studies and the reliability of the TOSRA. Given that this survey instrument has been proven valid and reliable in a range of contexts, it was considered a suitable choice for use in this study.

Klopfer (1971) made a significant contribution to studies related to attitudes towards science. He categorised attitudes towards science using six subcategories: the manifestation of favourable attitudes towards science and scientists, the acceptance of scientific inquiry as a way of thought, the adoption of scientific attitudes, the enjoyment of science learning experiences, the development of interests in science and science-related activities, and the development of an interest in pursuing a career in science or science-related work (Sook & Hooi, 2016). Based on Klopfer's classification, Fraser (1981) developed the TOSRA, which consists of seven constructs, as shown in Table 3.3.

The TOSRA measures science-related attitudes among secondary school students using seven distinct science-related attitudes. It comprises a total of 70 items, with 10 items in each of the seven scales, those being: Social Implications of Science, Normality of Scientists, Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science and Career Interest in Science.

Half of the TOSRA items were negatively worded, as per the original version developed by Fraser (1981). Students responded to the TOSRA items using a five-point Likert scale of strongly agree, agree, not sure, disagree and strongly disagree to express their degree of agreement. The TOSRA items are organised cyclically, whereby questions related to each scale appear in a cyclical order, for example, items 3, 10, 17, 24, 31, 38, 45, 52, 59 and 66 are all from the Attitude to Scientific Inquiry scale. Students were unaware of which item related to which scale. All the original items of the TOSRA were included in the study. A full copy of the items included in the TOSRA may be found in Appendix 3.

Table 3.3 Klopfer's (1971) classification and sample item for each Test of Science Related Attitudes (TOSRA) scale

Scale	Klopfer's (1971) Classification	Sample Item
Social Implications of Science	Manifestation of favourable attitudes towards science and scientist	Money spent on science is well worth spending. (+)
Normality of Scientists	Acceptance of scientific inquiry as a way of thought	Scientists usually like to go to their laboratories when they have a day off. (−)
Attitude to Scientific Inquiry	Acceptance of scientific attitudes 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	Adoption of 'scientific attitudes'	I am curious about the world in which we live. (+)
Enjoyment of Science Lessons	Enjoyment of science learning experience	I dislike science lessons. (−)
Leisure Interest in Science	Development of interest in science and science-related activities	I would like to belong to a science club. (+)
Career Interest in Science	Development of interest in pursuing a career in science	I would dislike being a scientist after I leave school. (−)

Note. Adapted from Fraser (1981). Items designated (+) are scored 1, 2, 3, 4, 5, respectively, for the responses strongly disagree, disagree, not sure, agree and strongly agree. Items designated (−) are scored in the reverse manner. This table is used with permission from Fraser (see Appendix 2).

3.6.2 What is Happening in this Class? Questionnaire

The WIHIC questionnaire, initially developed by Fraser et al. (1996), was used to assess students' perceptions of the science classroom learning environment. The WIHIC combines scales from a range of existing questionnaires but was modified to include new scales that relate to contemporary education, those being Equity and Constructivism. The WIHIC has seven eight-item scales that assess different dimensions of the learning environment (Aldridge et al., 1999). Moos (1976) divided the human environment into three dimensions: Relationship, System Maintenance and Change, and Personal Growth. He argued that these three dimensions underpin all socially created environments; therefore, vastly different educational environments can be investigated using these dimensions. The scales in the WIHIC fulfil Moos's scheme because they cover all three dimensions. Numerous past studies have found the WIHIC to be valid and reliable, including research involving middle school students in the US (Ogbuehi & Fraser, 2007) and middle school students in Australia (Aldridge et al., 1999; Deieso, 2018; Martin-Dunlop, 2013; Velayutham & Aldridge, 2013). Given the consistent evidence of strong reliability and validity (see Section 2.2.2.9 for more information), the WIHIC was considered a sound choice for use in this study.

The WIHIC includes 56 items, with eight items in each of seven scales: Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation and Equity. Table 3.4 describes each of the seven scales of the WIHIC, a sample item and how the scale aligns Moos's (1974b) dimensions (Relationship, Personal Development, System Maintenance and Change). The WIHIC does not include negatively worded or reverse-scored items; Barnette (2000) argued that this minimises or eliminates unnecessary confusion. The questionnaire items were presented in seven blocks under each of the WIHIC scales, with the wording for the response statements being concise and straightforward to ensure minimal confusion by the students undertaking the survey.

Items in each scale were responded to using a five-point frequency response scale of almost never, seldom, sometimes, often and almost always. A copy of the items included in the WIHIC is provided in Appendix 4.

Table 3.4 Scale description, sample item and Moos's (1974b) schema for each scale in the What Is Happening in This Class? (WIHIC) questionnaire

Scale Name	Scale Description	Sample Item	Moos' (1974) Schema
Student Cohesiveness	The extent to which students know, help and are supportive of one another	In this class, I get help from other students.	R
Teacher Support	The extent to which the teacher helps, befriends, trusts and is interested in the students	The teacher talks with me.	R
Involvement	The extent to which students have attentive interest, participate in discussions, do additional work and enjoy the class	I discuss ideas in class.	R
Investigation	The extent to which skills and processes of inquiry and their use in problem-solving and investigations are emphasised	I find out answers to questions by doing investigations.	P
Task Orientation	The extent to which it is important to complete activities planned and to stay on the subject matter	I know how much work I have to do.	P
Cooperation	The extent to which students cooperate rather than compete with one another on learning tasks	I learn from other students in this class.	P
Equity	The extent to which students are treated equally by the teacher	I get the same opportunity to answer questions as other students.	S

Note. R = Relationship, P = Personal Development, S = System Maintenance and Change. All items are scored 1, 2, 3, 4 and 5, respectively, for the responses of almost never, seldom, sometimes, often and almost always. This table is adapted from Giles (2019) with her permission (see Appendix 5).

3.6.3 Interviews

Phase 3 of the study involved the collection of interview data using in-depth, semi-structured interviews. Following the quantitative data collection (conducted in Phases 1 and 2), analysis was undertaken to investigate whether differences in student attitudes and perceptions of the learning environment for the two administrations were apparent. The findings from the quantitative data collection highlighted trends in the data that were used to guide the development of questions for the initial semi-structured interviews (carried out in Phase 3). Interviews held with students (sample selection is described in Section 3.4.3) provided causal information about their responses to the surveys and information that was not provided in the survey, such as contextual information about the primary schools that the students attended and the facilities available. In line with the interpretivist stance taken for the study, interviews allowed students "to discuss the interpretations of the world in which they live, and to express how they regard situations from their own point of view" (Cohen et al., 2000, p. 349).

In-depth interviews, as opposed to focus group interviews, were considered appropriate because they allow the researcher to probe the students' responses to obtain greater detail and context (Kvale, 2007). Further, given the researcher asked questions directly related to individuals' responses to surveys, in-depth interviews were deemed a more appropriate method when compared with focus group interviews.

Semi-structured interviews were considered appropriate because they provide consistency across interviews while allowing for flexibility and openness to explore additional questions if they arise (Creswell, 2008; Kvale, 1996, 2007). Semi-structured interviews involved the use of key questions to guide the interview and allowed participants to explore lines of interest, as recommended by Kvale (2007). Open-ended interviewing facilitated the ability to pursue topics that emerged and provided further insight into, and opportunity to learn more about, the students' beliefs and lived everyday world from the students' perspectives.

In this study, the interview schedule included three phases (Gillham, 2000), the introductory phase, the interview's central core and bringing the interview to a close (see Figure 3.3). In the introductory phase, the interviewees were informed of the purpose of the interview and the research project in which they were participating and the probable length of the interview. Following the communication of the purpose of the project and length of interview, information was shared regarding the recording and confidentiality of the data, and the interviewee was then invited to begin.

The central core of the interview included a limited number of questions because, according to Gillham (2000), an elaborate schedule with too many questions can easily cause the interviewer to lose their way. The questions developed were all on-topic but were also all distinctly different. Since the interviews were semi-structured in design, the main questions were 'open', allowing the interviewer to raise topics but ensuring that the answers were entirely up to the interviewee (Gillham, 2000). To ensure the interviews elicited depth, richness and detail, they were structured using a mixture of three types of questions: central, follow-up and probes (Rubin & Rubin, 2004). As suggested by Rubin & Rubin (2004), and in keeping with the interpretivist paradigm, I ensured that I used a responsive interviewing model. Hence, when interviewing, I looked for detail and depth, which delivered thematically rich answers.

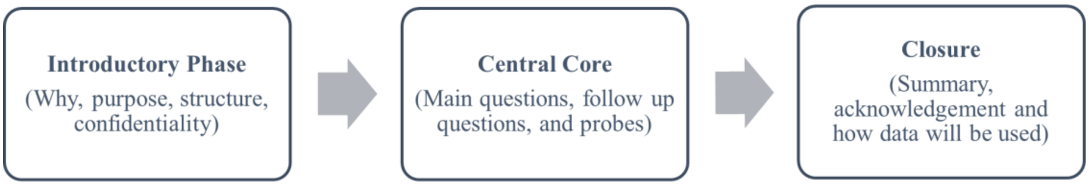

Figure 3.3 Structure of the semi-structured interviews

The schedule ensured that the question order was logical, starting with questions about the interviewee's primary school experience and then secondary school experience. Therefore, the interview schedule included questions that sought to discover the core differences between the students' primary and secondary schools, which could help explain the statistical differences between Phase 1 and Phase 2 of the quantitative data collection and also support understanding of gender differences. Based on students' responses to these questions, further questions were asked to explore the reasoning behind the differences related to attitudes towards science and the classroom environment. The questions provided in the interview schedule used during Phase 3, Stage 1 can be found in Appendix 6, and those provided in Phase 3, Stage 2 can be found in Appendix 7. In bringing the interview to a close, I summarised what I heard, thanked the interviewee for their time and contribution, and shared how this interview data would be used.

All interviews took place at the schools that the interviewees attended. They occurred during the students' scheduled science lessons in a private room. Each interview lasted for approximately 30 minutes. These interviews occurred through web conferencing in a private room with individual students for one of the regional schools. I (the researcher) conducted all the interviews, which allowed me to remain close to the data, identify and pursue emerging themes, and gauge when saturation was reached. All interviews were audio recorded and transcribed verbatim.

3.6.4 Achievement Data

Teachers were asked to provide an end-of-semester grade for students who participated in the surveys and a one-sentence comment regarding students' attitude and participation in science lessons. It should be noted that not all teachers provided this detail. Those who did provide the students' grades were asked to consider the average of the various assessments completed by the interviewees in science over 20 weeks (half a year). The grading was uniform across all schools involved in the study, reporting on student achievement in Australian schools as set out in regulation 59 of the *Australian Education Regulation 2013* (Cth). The achievement was reported as A, B, C, D or E (with A being the highest and E being the lowest) and then converted to a five-point scale for analysis.

3.7 Data Analysis

This section details how and when the mixing of the data occurred (Section 3.6.1). Following this, the analysis for each research question is detailed (Section 3.6.2). Lastly, the thematic analysis for the qualitative data is described (Section 3.6.3).

3.7.1 Mixing of the Data

In the design for the current study, the collection and analysis of quantitative data took precedence. This was a considered decision to allow the qualitative data to build on the quantitative results. Conceptually, there are three overall strategies for mixing quantitative data: the two data types may be merged, one may be embedded with the other or one may be connected with the other (Creswell, 2008). In this study, the strategy used for mixing the data was connecting the data types. Connecting the data occurs when the analysis of one type of data leads to (and thereby connects to) the need for the other type of data (Creswell, 2008). In my study, the quantitative results lead to the subsequent collection and analysis of the qualitative data through semi-structured interviews. The mixing of both quantitative and qualitative data occurred at two points. The first point was after the quantitative collection; the second point was at the analysis stage after the qualitative collection. After the analysis of the qualitative data, deeper insights into the research questions were provided (see Creswell, 2008; Lan et al., 2015; Watson et al., 2017).

3.7.2 Analysis by Research Question

The following sub-sections report how data were analysed to address each of the research questions. Regarding research question 1, the data were analysed to examine the reliability and validity of the surveys, as described in Section 3.7.2.1. For research question 2, the data were analysed to examine girls' attitudes and learning environment perceptions in secondary science classes, as described in Section 3.7.2.2. For research question 3, the data were analysed to examine differences for girls in coeducation and single-sex schools in terms of their attitudes towards science and learning environment perceptions, as detailed in Section 3.7.2.3. For research question 4, the data were analysed to examine the differences in girls' attitudes towards science and perceptions of the learning environment in primary and secondary school settings, as detailed in Section 3.7.2.3 For research question 5, the data were analysed to examine differences between girls and boys in secondary school on terms of their attitudes towards secondary school science classes and perceptions of the learning environment, as detailed in Section 3.7.2.3. For research question 6, data were analysed to examine whether relationships exist between girls' perceptions of their science classroom environment and their attitudes towards science and science achievement, as detailed in Section 3.6.2.4. Lastly, Section 3.6.3 describes the qualitative data analysis used to answer research questions 3 to 5. Table 3.5 provides a summary of the research questions, data type, instrument used and type of analyses.

Table 3.5 Research question, data type and instrument for analyses

Research Question	Data Type	Instrument	Analyses
Research question 1	Quantitative	• Test of Science Related Attitudes (TOSRA) • What is Happening in this Class? Questionnaire (WIHIC)	• Bartlett's test of sphericity and the Kaiser–Meyer–Olkin test • Principal axis factor analysis • Oblique rotation • Internal consistency reliability • One-way analysis of variance (ANOVA) • Descriptive statistics
	Qualitative	—	—
Research question 2	Quantitative	• TOSRA • WIHIC	• Descriptive statistics, including average items means average item standard deviations • Box and whisker plots
	Qualitative	—	—
Research question 3	Quantitative	• TOSRA • WIHIC	• Multivariate analysis of variance (MANOVA) • Effect sizes
	Qualitative	• Semi-structured interviews	• Inductive approach to thematic analysis
Research question 4	Quantitative – Phase 1 and Phase 2	• TOSRA • WIHIC	• MANOVA • Effect sizes
	Qualitative – Phase 1 and Phase 2	• Semi-structured interviews	• Inductive approach to thematic analysis
Research question 5	Quantitative	• TOSRA • WIHIC	• MANOVA • Effect sizes
	Qualitative	• Semi-structured interviews	• Inductive approach to thematic analysis
	Qualitative – Phase 1 and Phase 2	• Semi-structured interviews	• Inductive approach to thematic analysis
Research question 6	Quantitative	• TOSRA • WIHIC • Achievement data	• Simple correlation • Multiple regression

3.7.2.1 Reliability and Validity of the Surveys (Research Question 1)

Evidence to support whether the instruments used to assess students' attitudes towards science and their perceptions of the learning environment were valid and reliable when used with secondary school students in South Australia was provided to answer research question 1. Statistical analyses were conducted to examine the factor structure, internal consistency reliability and ability to differentiate between groups. The sample included all the students in each data set (Phase 1 and Phase 2). The data collected from the survey responses in Phase 1 and Phase 2 were analysed separately in all cases.

Before analyses, the suitability of the data was examined using Bartlett's test of sphericity and the Kaiser–Meyer–Olkin (KMO) test. The criteria used to assess the appropriateness of the data were that "Bartlett's test of sphericity should be statistically significant $p < .05$ and the Kaiser–Meyer–Olkin value should be .6 or above" (Pallant, 2013, p. 190).

As a first step, principal axis factor analysis was used to examine the underlying structure and groupings within the variables of the two instruments (TOSRA and WIHIC). Oblique rotation was selected because two or more factors (i.e., latent variables) were likely to be correlated (Pallant, 2010). According to Pallant (2020), oblique rotation simplifies the mathematical description of manifest variables by reorienting the factors to fall closer to clusters of vectors representing manifest variables. The criteria for retaining items, as recommended by Field (2005), was that each item should load at .40 or more on I priori scale and less than .40 on all other scales.

To validate further the questionnaires, analysis using internal consistency reliability was used to determine the extent to which each item in a scale assessed a similar construct. Cronbach's alpha coefficient was used as an index scale of internal consistency for each scale. Yusoff (2012) and Schmitt (1996) recommended a minimum of .50 be used to indicate the suitability of the internal consistency reliability of different scales. Different levels of analysis for internal consistency reliability were used in the current study, including the individual and class mean.

A one-way analysis of variance (ANOVA) was computed to determine whether students' responses to different scales could differentiate between classes. Theoretically, students in the same class should perceive the learning environment relatively similarly, but differently from students in other classes. Therefore, the ANOVA results were used to examine if each questionnaire scale could differentiate between student responses in different classrooms.

Finally, the correlation of a scale with other scales was examined to ensure discriminant validity. The factor correlation matrix, generated during oblique rotation for each data collection phase, was used to examine the interrelatedness of the factors within each instrument. The discriminant validity requirement was that each factor correlation needed to be below 0.80, according to Brown (2006). A relatively low correlation would suggest a minimal overlap of one scale with other scales and compare favourably with other discriminant validity studies involving the TOSRA and the WIHIC.

3.7.2.2 Secondary School Girls' Attitudes and Learning Environment Perceptions

To provide an overview of the attitudes and learning environment perceptions of secondary school girls, research question 2 was delineated. Descriptive statistics, including the average item means and average item standard deviations, were used to summarise girls' attitudes towards science and their learning environment perceptions in secondary school. In addition, box and whisker plots were used to provide information about the variation of responses for each TOSRA and WIHIC scale.

3.7.2.3 Examining Differences (Research Questions 3, 4 and 5)

Research questions 3, 4 and 5 sought to examine differences. As described below, to answer these research questions, multivariate analysis of variance (MANOVA) and effect sizes were used. To provide a fair comparison between boys and girls, analyses used only data collected from students in co-educational schools. Further, because boys and girls were not found in equal numbers in each class, the within-class mean was used.

Before conducting the MANOVAs, preliminary assumption testing on the data was carried out to check for violations of normality, linearity and homogeneity of variance-covariance matrices. To test multicollinearity, correlations between the dependent variables were found. These ranged between .02 to .68 for the scales of the TOSRA and between .16 to .43 for the scales of the WIHIC. Once confirmed, a MANOVA was performed separately for each instrument using the attitude and learning environment scales as the dependent variables. Wilks' lambda was checked to ensure that the significance level was less than 0.05, which in turn ensured a statistically significant difference between the two groups/administrations. Once these conditions were satisfied, the univariate ANOVA was interpreted.

Finally, to provide an indication of the magnitude of the differences, as recommended by Thompson (2001), the effect sizes were calculated using Cohen's *d* formula:–$(M2 - M1) / SDpooled$.

For this study, effect sizes were used and sorted between small (0.10), medium (0.25) and large (0.40), as recommended by Cohen (1988).

Research question 4 focused on students from co-educational schools only. Given that boys and girls were not found in equal numbers in every class, the within-class gender mean was used to provide a matched pair of means – one within-class mean for girls and one within-class mean for boys. For this analysis, student sex was used as the independent variable.

3.7.2.4 Environment – Outcome Associations (Research Question 6)

Analyses were undertaken to determine whether relationships existed between students' perceptions of their science classroom environment and their attitudes towards science and science achievement (research question 6). Statistical analyses involved simple correlation and multiple regression analyses to assess the relationships. The environment scales constituted the independent variables, and the attitude scales were the dependent variables. For environment and attitude associations, analyses drew on the data collected from the survey responses in Phase 1 and Phase 2, and the analysis was conducted separately for each phase. For environment and achievement associations, analyses drew on the data collected from the survey responses in Phase 2. The environment scales constituted the independent variables, and the achievement scores were the dependent variables.

First, simple correlation analysis (r) was used to examine the bivariate relationship between one environment scale and one attitude scale and between one environment scale and achievement score. This analysis provided information about the correlations between each learning environment scale, attitude scale and achievement score. However, it did not provide information about which classroom environment scales contributed most to the variance in attitudes or achievement. This analysis was limited because it did not provide information related to causation; it only reported which variables demonstrated a linear relationship. Even if a strong association between two variables existed, this analysis did not confirm that one caused another.

Multiple regression analysis, with the individual as the unit of analysis, was used to examine the multivariate association between each attitude scale and the set of seven learning environment scales and between each achievement score and the set of seven learning environment scales. The attitude scales and achievement scores constituted the dependent variables, and the learning environment scales the independent variables. The standardised regression coefficients (β) were examined to determine which environment scales contributed to a variance in the attitude scale or achievement score when all other scales were mutually controlled.

3.7.3 Thematic Analysis: Providing Causal Explanations (Research Questions 3, 4 & 5)

For the analysis of the qualitative data, thematic analysis was used. Thematic analysis has become widely recognised as a unique and valuable method for data analysis. According to Braun and Clarke (2012),

> Thematic Analysis is a method for systematically identifying, organizing, and offering insight into patterns of meaning (themes) across a data set. Through focusing on meaning across a data set, thematic analysis allows the researcher to see and make sense of collective or shared meanings and experiences. (p. 2)

An inductive approach to thematic analysis was employed in this study so that new themes and findings could emerge throughout the study. An inductive approach to data coding and analysis is driven by what is in the data (Braun & Clark, 2012). Therefore, coding and theme development was directed by the content of the data.

I followed the six steps to thematic analysis developed by Braun and Clark (2012): familiarisation, coding, generating themes, reviewing themes, defining and naming themes, and, finally, writing up. The steps are identified in Figure 3.4, and the following text describes how these applied to my study.

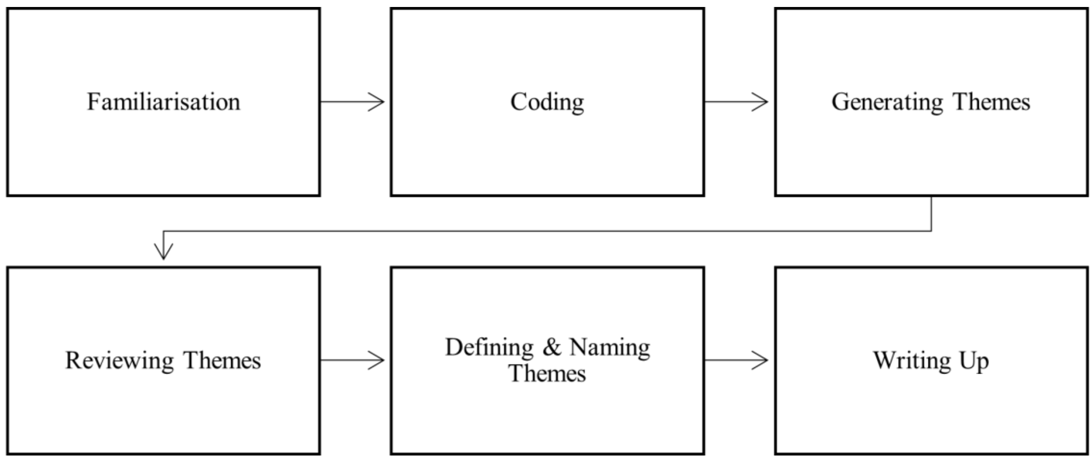

Figure 3.4 Thematic analysis approach recommended by Braun and Clarke (2012)

During the first phase, *familiarising myself with the data,* I immersed myself in the data by listening to the audio recordings of the interviews and reading the transcripts of interviews actively and analytically. During this phase, I sought to think critically about what the data meant. As I was reading the transcripts, I made notes and highlighted items of potential interest.

The second phase, *generating initial code*s, occurred after reading the entire qualitative dataset numerous times. In this way, I became intimately familiar with the dataset's content and noticed aspects that were relevant to my research questions. Through this process, I made notes on the entire qualitative dataset as well on individual transcripts (Braun & Clark, 2012). This systematic analysis of the data enabled me to generate initial codes. The codes identified and provided a label for a feature of the data that was potentially relevant to the research questions and helped to provide causal explanations for the quantitative data.

The third, fourth and fifth phases, *searching for themes*, *reviewing potential themes*, and *defining and naming these themes* occurred after generating initial codes. After generating the initial codes, I started to identify themes using these codes. I again immersed myself in the data, listening to and reading each transcript numerous times, as recommended by Creswell (2008) and Widodo (2014). Consequently, I was able to engage deeply with the data, identify emerging themes and listen for particular points of interest. Widodo (2014) explained that

> transcribing verbal data affords a teacher researcher the opportunity to carefully listen to, pay close attention to, and think deeply of digitally recorded data situated within a particular interview context. This socio-cognitive activity involves how researcher's mind interacts with spoken text. (p.102)

I then organised and developed my major themes and triangulated the emerging themes across the qualitative and quantitative datasets. Using an interpretivist stance, the quantitative and qualitative data were analysed in a complementary manner. I was able to use the results from the qualitative interviews to elaborate, enhance and clarify the results from the quantitative survey results (Halcomb & Hickman, 2015).

To obtain the major themes, I underwent a coding process in which I first focused on 'relevant text'. The relevant text is related to the specific research concerns (Auerbach, 2003). I then searched for repeating ideas whereby different students had used similar words or phrases to express the same idea (Auerbach, 2003). Finally, I determined key themes: groups of repeating ideas that had something in common were used to form the qualitative themes. A theme is an implicit topic that organises a group of repeating ideas (Auerbach, 2003).

Once the themes had been determined, they were provided with a code. Themes appearing in the transcribed interviews were registered, classified and re-classified based on an active search for confirming and disconfirming evidence in the interviews (Kvale, 2007).

Next, I again listened to each interview recording and read each transcript multiple times, collating relevant words, phrases, sentences or sections linked to the identified themes, which provided me with valuable causal information and context. Quotes were also identified and linked to the key themes, which strengthened the data. The key themes were analysed to find relationships to the preconceived themes found in the quantitative data. It became evident that the themes in both the qualitative and quantitative data sets had strong links.

The sixth phase, *producing the findings,* occurred after organising the repeating ideas and themes across the quantitative and qualitative datasets. Finally, I organised my theoretical constructs into a theoretical narrative, which linked to the research questions.

3.7.4 Data Verification

Willis, Jost & Nilakanta (2007) argued that “when it comes to a discussion about how interpretive paradigms treat post-positivist concepts such as reliability, validity and generalisation there is less consensus” (p. 224). Various quality criteria for mixed methods research have been proposed, and many of these generally reflect a post-positivist worldview (McChesney, 2017). To guarantee quality criteria, I drew on the interpretivist paradigm to inform the collection and analysis of my data while keeping in mind the post-positivist quality criteria as a guide. Therefore, I was able to utilise quality criteria measures from both.

For an interpretivist paradigm, Willis, Jost & Nilakanta (2007) suggested six techniques to instil confidence in the quality of the research. These comprise member checks, participatory research methods, extended experience in the environment, peer review, researcher journaling and audit trails. For my study, I incorporated members checks and researcher journaling techniques.

To employ the technique of member checks, I checked the emerging conclusions with participants. When interviewing students, I summarised their answers and, in some cases, restated what they had said to ensure I accurately represented their responses. When using the technique of researcher journaling, I recorded my thinking as I collected and analysed the data, which meant I could explain to others how I had arrived at my conclusions, particularly throughout the qualitative data collection and analysis.

According to Yin (2002), case study researchers who work within conventional paradigms need to guarantee construct validity, internal validity, external validity and reliability. One way to gain construct validity is through gathering several sources of evidence and triangulating these sources. Internal validity can be established through methods such as pattern matching. External validity is gained through analytic generalisation and, finally, reliability is gained through case study protocols and databases.

Guba and Lincoln (1981) devised criteria parallel to those of the conventional paradigm to suit a naturalistic paradigm. Guba and Lincoln (1981) believed that it is important to examine the study's trustworthiness to evaluate a research study's worth. To establish trustworthiness within the naturalistic paradigm, you need to establish *credibility*, *transferability*, *dependability* and *confirmability*. Therefore, for my study, credibility was equivalent to internal validity, transferability was equivalent to external validity reliability, dependability was equivalent to reliability and confirmability was equivalent to objectivity (Lincoln & Guba, 1986). These were the criteria for trustworthiness. See Table 3.6.

Table 3.6 Criteria of trustworthiness within the conventional and naturalistic paradigms

Conventional Paradigm	Naturalistic Paradigm
Internal validity	Credibility
External validity	Transferability
Reliability	Dependability
Objectivity	Confirmability

As additional measures to those described in the preceding paragraphs, to verify my data I used a series of techniques to establish credibility, transferability, dependability and confirmability (Lincoln & Guba, 1986).

Credibility is confidence in the 'truth' of the findings (Lincoln & Guba, 1986). Concerning *credibility* and to ensure *internal validity*, I ensured that the realities of the students were represented appropriately. To do this, I ensured that there was a prolonged engagement at each school. Since this study involved three phases of data collection, I was able to engage with the same students over an extended period. Engaging over a prolonged period enabled me to test the biases and perceptions of both myself and the participants in the study. I could also identify salient characteristics to understand the context more deeply and interpret the data. Because I ensured prolonged engagement, in turn I was able to ensure persistent observation of the data. Consequently, I was able to form a deep understanding of 'pervasive' qualities and salient characteristics. Moreover, I was able to gain further understanding about the atypical but critical characteristics and eliminate those that were irrelevant (Guba & Lincoln, 1982). In addition, I implemented triangulation of the data, which enabled me to cross-check the data and interpretation.

Transferability concerns demonstrating that the findings can be applied in other contexts (Lincoln & Guba, 1986). *Dependability* shows that the findings are consistent and could be repeated (Lincoln & Guba, 1986). In relation to *transferability* and *dependability* and to ensure *external validity* and *reliability*, the sample data collected were generally representative of the population to which generalisation would be sought. Since both stratified and purposive sampling methods were used in this study, this maximised the range of information collected and provided conditions for theory grounding (Guba & Lincoln, 1982). Further, I provided significant information about the context to support the ability to transfer to a second or similar context. Therefore, this study could be repeated under the same circumstances in another place and time, which also enhances its *dependability* and *reliability* (Guba & Lincoln, 1982).

Confirmability refers to the degree to which the results could be confirmed or corroborated by others. Finally, concerning *confirmability* (Guba & Lincoln, 1981) and *objectivity* (Yin, 2002), I ensured I was always mindful of my objectivity and I acknowledged my bias throughout the research.

3.8 Ethical Considerations

Prior to the commencement of this research, ethical approval was gained from Curtin University, approval number SMEC 52-12 (see Appendix 8 for a copy of the approval letter), the Department of Education and Child Development (see Appendix 9 for a copy of the approval letter) and the Catholic Education Office of South Australia (see Appendix 10 for a copy of the approval letter). In addition to these ethics' approvals, before the study commenced and throughout the research, consideration was given to addressing several ethical issues. This section describes how these ethical issues were addressed to ensure the safety of the participants associated with the present study, including issues related to informed consent (Section 3.7.1), privacy and confidentiality considerations (Section 3.7.2), data storage (Section 3.7.3) and minimising disruption throughout the gathering of data (Section 3.7.4).

3.8.1 Informed Consent

Informed consent is an ethical and legal requirement of research and is a voluntary agreement to participate in the research. As stated by Cohen et al. (2000), "The principle of informed consent concerns autonomy, and it arises from the participant's right to freedom and self-determination" (p. 122). Informed consent implies that all participants understand what will happen throughout the research and their rights and responsibilities. It also states that the choice to participate is freely given and there will be no negative consequences for non-participation.

To ensure that participants provided informed consent, they were provided with the information related to the subject of the research and their rights and responsibilities. Before the study began, information about the research was provided to all participants, namely, teachers, students, principals and parents. This section describes the information provided to the different participants.

3.8.1.1 Informed Consent: Students

Students were provided with an information sheet that outlined the nature of the research, their roles in the research and the expectations of them when participating in the research, as well as their rights. This information sheet detailed the purpose of the research, stating that it investigated the relationship between student attitudes and classroom environment and achievement in different settings. It shared the key research objectives and the process of how the data would be gathered. The information sheet clearly explained, in plain language, the student's role in the research. The sheet explained that students would be required to complete the two surveys twice, once at the start of the year and once eight months later. The information sheet also clarified that the student could be invited to participate in an in-depth interview related to their responses to the surveys.

Notably, the information sheet clarified that the student's involvement in the study was entirely voluntary and that they had the right to withdraw at any stage. It noted that if they had signed the consent form (which was attached to the information sheet), they had agreed to participate and to allow me to use their data in my research. The information sheet explained how the confidentiality of the students would be safeguarded and how the data collected would be treated with confidentiality. It was made clear that although students were required to provide their names on the survey, once their responses (Phase 1 and Phase 2) were matched, this identifying information would be removed. Finally, the information sheet included the contact details for me, as the researcher, my research supervisor and the ethics office at Curtin University. Before administering the surveys and the commencement of the interviews, students were given time to read the information sheet and ask questions.

A consent form was included at the back of this information form. By signing the consent form, students agreed that they had been provided with the participation information sheet and had understood:

- the purpose and procedures of the study
- that their involvement was voluntary and that they could withdraw at any time
- that no personal identifying information would be used in any published materials
- that all information would be securely stored for at least seven years before a decision would be made regarding whether it should be destroyed.

All informed consent forms were signed and returned to the school before commencing the research. See Appendix 11 for a copy of the Student Information and Consent Form.

For students involved in interviews, another information and consent form were provided to them (see Appendix 12 for a copy). This information sheet was also provided as a paper copy, and students were given time to read it before the interviews began. This information sheet contained similar information to the first, explaining who I was and the purpose of the research. The information sheet explained that students had already been surveyed and that these interviews sought information about differences. It provided information about the interview duration and when it would be scheduled (to minimise disruption). It was made clear that, although students would initially identify themselves, the information they provided would remain confidential and that all identifying information would be removed after analysis. Finally, the students were provided with contact details for myself as the researcher and my research supervisor. Students were given time to read the information sheet and ask questions before the interviews began. Again, a consent form was included at the back of this information form. By signing the consent form, students agreed that they had been provided with the participation information sheet and understood it.

3.8.1.2 Informed Consent: Parents

Given that students were under 18 years of age, it was important to ask for parental consent. Parents were provided with similar information to the students, but in language more fitting for an adult. The information sheet outlined the nature of the research. It clearly explained their child’s role within the research. It explained that their son or daughter would be required to complete the two surveys twice, once at the start of the year and once eight months later. The information sheet also stated that their child may be selected for an in-depth interview to respond to questions related to the surveys.

Importantly, the information sheet clarified that their child’s involvement in the study was entirely voluntary and that their child had the right to withdraw at any stage. It noted that if they had signed the consent form (attached to the information sheet), they had agreed that their son or daughter could participate in the study and that I, the researcher, could use their child's data in my research.

Parents were asked to return the consent forms prior to the commencement of the study. Only those students whose parents had consented for them to be in the study were included.

3.8.1.3 Informed Consent: Teachers

Data were not collected directly from teachers for the purpose of this research. However, since the students in each class were asked to respond to questions related to their perceptions of the learning environment created by teachers, teachers were asked to provide consent for the research to be conducted in their science class. As with the other participants, teachers were provided with an information sheet that detailed the research purpose and clearly explained the teacher's role. As well as sharing the key research objectives and the process of how the data would be gathered, the sheet explained that teachers would be asked to administer two surveys twice, once at the start of the year and once eight months later. Further, some teachers were asked to provide an end-of-semester grade for each student who participated in the surveys and a one-sentence comment regarding students' attitude and participation in science lessons.

In addition, the information sheet clarified that their own involvement, and that of their students, was voluntary and that they had the right to withdraw at any stage. It noted that on signing the consent form (which was attached to the information sheet), they agreed to participate in the study and permitted me to use their data in my research.

All informed consent forms were signed and returned to the school before commencing the research. See Appendix 14 for the Teacher Information and Consent Form.

3.8.2 Privacy and Confidentiality

Cohen et al. (2017) stated that one way of addressing privacy is by anonymity. To ensure privacy and confidentiality for all participants and schools, all data were given anonymous codes.

During the collection of the surveys (during Phases 1 and 2), students were required to provide their names on the surveys to allow their responses in Phases 1 and 2 to be matched. While waiting for Phase 2 surveys, Phase 1 paper copies were kept in a locked cabinet with access only available to myself, the researcher. On collection of the Phase 2 data, the data from both phases were entered into an excel spreadsheet. Once the student responses to Phases 1 and 2 were matched on the electronic database, students' names were removed and replaced with a code. The paper copies of the surveys were kept in a locked cabinet in the researchers' study until all analyses were completed, and then they were destroyed.

All interviews were audio recorded onto an electronic device. In between interviews, this device was kept secure in a locked cupboard. After the interviews, the audio files were uploaded onto a password-protected computer and named appropriately. Once transcribed, the students' names were replaced with a code. The formula for the code included the type of data (e.g., 'Int' for interview data), followed by the school type (i.e., 'CE' for co-educational or 'SS' for single-sex), the stage during which the interview took place (i.e., 'S1' for Stage 1 and 'S2' for Stage 2), the sex of the interviewee (i.e., 'F' for female and 'M' for male) and finally the interview number. An example of a complete code is 'Int-CE-S1-M-01', indicating an interview undertaken at a co-educational school during Stage 1 of Phase 3, that the student was a male and that the code number was 1. Only I, the researcher, and my supervisor had access to the qualitative information during the analysis. It should be noted that although I was able to identify which participants provided which information, this connection was in no way made public.

3.8.3 Data Storage

The hard-copy paper-based data (questionnaires and achievement data) and informed consent forms were stored in a locked filing cabinet during the data collection and transferred to an electronic format. After the study, all paper-based data were destroyed. All electronic data (survey and achievement data and interview recordings and transcripts) were stored on my computer and backup disk, and no one else, apart from my supervisor, had access to it.

During data analysis, all electronic data remained on my secured computer. This computer was password protected and was backed up regularly to avoid loss of data and information. During the qualitative data analysis, I took many hand-written notes and drew images to understand better what I was hearing. These notes and images were stored in the locked filing cabinet along with the completed paper-based questionnaires and informed consent forms.

The raw data in electronic form collected during the study will be kept at Curtin University for a period of seven years after the date of thesis publication in accordance with the Western Australian Sector Disposal Authority (section 14.6.5). After this time, all files will be destroyed.

3.8.4 Minimising Disruption

To reduce any harm caused to the participants, it was essential to minimise its potential causes, which was ensured at different stages of the study. During the study, to minimise disruption, teachers were provided with all the necessary materials and given sufficient time to plan a suitable window to administer the surveys. Therefore, disruption to the normal timetable and programs was kept to a minimum. In most cases, teachers administered the surveys during their scheduled science lesson.

The qualitative interviews were organised at a time that suited the teacher and student best. In most cases, these occurred during the students' scheduled science lessons or break times. The researcher communicated with the teachers to schedule an appropriate time that ensured students did not miss any curriculum content because of the research. If curriculum content was missed, the teacher met with the students to teach them what had been missed.

3.9 Chapter Summary

This chapter described and justified the research methods used to answer the six research questions. It reiterated the research objectives and detailed the research design to address the objectives. It provided details concerning the research paradigm, mixed methods design, sample, phases and data collection methods. Additionally, the chapter explained the selection of the quantitative instruments and the qualitative instruments and reliability of the data. It described which methods of data analysis were used. Lastly, it considered ethical considerations pertinent to the study, including ethical approvals sought, informed consent, privacy and confidentiality, and any other factors, including disruptions to the site and learning.

The research was designed with an interpretivist paradigm using a mixed methods explanatory sequential design. The mixed methods approach combined quantitative and qualitative methods to explore the research questions, thereby offering rich insights and capturing of information that might be missed if only one research design had been used. The explanatory sequential design involved three overlapping phases of data collection. The first and second phases involved collecting quantitative data, and the third phase involved gathering qualitative data that was used to explain the quantitative findings (Caruth, 2013).

The sample space was defined as students from science classes in Year 8 from a range of secondary schools in South Australia, and the sample was drawn from 10 secondary schools in South Australia. The selection of the 10 schools involved a mix of both single-sex all-girls (n = 2) and co-educational schools (n = 8), and schools were selected from both regional South Australia (n = 3 co-educational schools) and metropolitan South Australia (n = 7, with two schools being single-sex all-girls and five schools being co-educational).

For the analysis of research questions 2, 3, 4 and 6, secondary students were used (130 girls). For question 4, only those girls who responded to both administrations

(Phases 1 and 2) were included, providing a total of 130 students, of whom 55 (approximately 42%) came from single-sex settings and 75 (approximately 58%) from co-educational settings. For the analysis of research question 5, a sample of 149 secondary science students were consulted, of whom 74 were boys and 75 were girls.

The collection of qualitative data occurred in two stages, referred to as Stage 1 and Stage 2. During Stage 1, a total of 26 students were interviewed. A further 16 girls were interviewed (from 13 single-sex and three co-educational schools) in Stage 2 to provide additional information related to research question 3. Therefore, when combined, the sample for interviews included a total of 19 girls from a single-sex setting, 13 girls from a co-educational setting, and 10 boys from a co-educational setting.

The instruments used to gather the data in the study included two surveys: The TOSRA (to assess students' attitudes towards science) and the WIHIC questionnaire (to assess students' perceptions of the learning environment). In addition, qualitative information was collected using in-depth, semi-structured interviews.

To assess the reliability and validity of the questionnaires (research question 1), statistical analyses were conducted to examine their factor structure, internal consistency reliability and ability to differentiate between groups. Analyses were conducted separately for the data collected from the survey administration in Phase 1 and Phase 2. To investigate whether differences in attitudes and student perceptions of the learning environment for the two administrations were statistically significant (research question 5), a MANOVA was performed separately for each instrument. To examine whether sex differences and school differences existed (research questions 3 and 4), a MANOVA and effect sizes were used. To address the sixth research question, simple correlation and multiple regression analyses were undertaken to determine whether relationships existed between students' perceptions of their science classroom environment and their attitudes towards science and science achievement.

For the analysis of the qualitative data (to answer research questions 3 to 5), an inductive approach to thematic analysis was used. This followed six steps:

familiarisation, coding, generating themes, reviewing themes, defining and naming themes, and, finally, writing up.

The study used several techniques to verify the data, including member checks and participatory journaling. Additional techniques were used to establish credibility, transferability, dependability and confirmability, including prolonged engagement, triangulation of the data, generalisation and acknowledgement of bias.

Finally, the chapter describes the considerations made concerning ethical issues throughout the study, including the process taken to obtain informed consent, how privacy and confidentiality were addressed, how the data were stored and, finally, how disruption was minimised at each site. Chapter 4 reports the results of the present study.

Chapter 4

RESULTS

4.1 Introduction

This chapter reports the results of my study. The results are reported in six sections, each of which addresses a different research question:

- Validity and Reliability of the Instruments (Section 4.2)
- Girls and secondary school science (Section 4.3)
- Differences for Girls in Different Settings (Section 4.4)
- Sex Differences (Section 4.5)
- Learning Environment – Outcome Relationships (Section 4.6)
- Chapter Summary (Section 4.7).

4.2 Validity and Reliability of the Instruments

The two surveys selected for this study had not been used with this population before. Therefore, as a first step, the study sought to provide evidence to support the reliability and validity of the instruments when used with this sample. Thus, the first research question asked:

Are the instruments used to assess students' attitudes towards science and their perceptions of the learning environment valid and reliable when used with secondary school students in South Australia?

As described in Chapter 3, statistical analyses were conducted to examine, separately for each survey, the factor structure, internal consistency reliability and ability to differentiate between groups (ANOVA results). These analyses were carried out separately for the data collected at Phase 1 and Phase 2 (N = 269 students in Phase 1 and 223 students in Phase 2). This section reports evidence to support reliability and validity for the TOSRA (Section 4.2.1) and the WIHIC (Section 4.2.2).

4.2.1 Reliability and Validity of the Test of Science-Related Attitudes

In this section, evidence to support the reliability and validity of the TOSRA, when used with this study's sample, is reported in terms of the factor structure (Section 4.2.1.1), internal consistency reliability (Section 0) and ANOVA results (Section 4.2.1.3).

4.2.1.1 Factor Structure

A check for suitability was performed before analysing the data, using the KMO measure and Bartlett's test of sphericity. The KMO value, according to Pallant (2020, p. 199), should be above .60, and "Bartlett's test of sphericity should be statistically significant at $p < .05$" (p.190). For these data, the KMO score was .84 for Phase 1 and .89 for Phase 2. These values were well above the .60 recommended for both datasets. Bartlett's test of sphericity was statistically 0.00 for both datasets, which also complied.

Principal axis factor analysis with oblique rotation was conducted separately for the data collected at each phase. Item analysis during factor analysis indicated that two of the scales (Adoption of Scientific Attitudes and the Leisure Interest in Science) were problematic for both data sets; therefore, all items in both scales were omitted from further analyses. In addition to these two scales, a further 24 items did not fit the criteria (loading at .40 or more on their own scale and less than .40 on other scales) and were omitted from all subsequent analyses. These items included item 24 from the Attitudes to Scientific Inquiry scale; items 19, 40, 54 and 68 from the Enjoyment of Science Lessons scale; items 14, 28, 35, 49 and 63 from the Career Interest in Science scale; items 1, 15, 29, 43, 57 and 64 from the Social Implications of Science scale; and items 2, 9, 16, 30, 37, 44, 58 and 65 from the Normality of Scientists scale.

Once problematic items had been removed, the modified version of the TOSRA comprised 28 items over five scales. All but three of these items loaded at .40 or above on their own scale and less than .40 on all other scales. The three exceptions were all from the Phase 1 dataset. Two items, items 9 and 57 (for the Normality of Scientists scale) did not load at .40 on their scale or any other scale. These items were retained because, first, their Cronbach's alpha coefficient was above .50 with the individual and class mean as the unit of analysis, which, according to Yusoff (2012) and Schmitt (1996), is considered an acceptable cut-off. Second, the eigenvalues for this scale were higher than 1.0, as recommended by Kaiser (1960). The third item, item 56 for the Career Interest in Science scale loaded above .40 on its own scale but also loaded on the Enjoyment of Science Lessons scale. A decision to retain this item was made because its removal affected the overall factor structure and the internal consistency reliability of the scale. Table 4.1 reports the factor loadings for the refined TOSRA instrument.

For data collected during Phase 1, the percentage of variance ranged from 4.83% to 26.11%, with a total percentage variance of 55.25%. The eigenvalues ranged from 1.35 to 7.31, and, since they were all greater than one, they met Kaiser's (1960) recommended cut-off threshold. For data collected during Phase 2, the percentage of variance ranged from 4.24% to 30.86%, with a total percentage variance of 59.83%. The eigenvalues ranged from 1.80 to 4.55; again, because they were all greater than one, they all met Kaiser's (1960) cut-off threshold.

4.2.1.2 Internal Consistency Reliability

Cronbach's alpha coefficients, used as a measure of internal consistency reliability, are reported in Table 4.2. For all but one TOSRA scale (Normality of Scientists), Cronbach's alpha coefficients were above .70 for both phases using both units of analysis. The exception was Normality of Scientists, for which Cronbach's alpha coefficients were all above .5 for both phases using both units of analysis, which satisfied Yusoff's (2012) and Schmitt's (1996) recommendations. In sum, the Cronbach's alpha coefficients for the data collected at Phase 1 ranged from .53 to .93 with the individual as the unit of analysis and from .55 to .95 with the class mean as the unit of analysis. Regarding data collected at Phase 2, Cronbach's alpha coefficients ranged from .70 to .94 for the individual as the unit of analysis and from .54 to .96 for the class mean as the unit of analysis.

Table 4.1 Factor loadings for the attitude TOSRA scales for data collected during Phase 1 and Phase 2

Item No.	Factor Loading									
	Attitude to Scientific Inquiry		Enjoyment of Science Lessons		Career Interest in Science		Social Implications of Science		Normality of Scientists	
	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
3	.56	.65								
10	.56	.46								
17	.62	.63								
31	.60	.60								
38	.46	.56								
45	.68	.66								
52	.48	.59								
59	.51	.54								
66	.46	.59								
5			.74	.70						
12			.77	.73						
26			.79	.72						
33			.76	.72						
47			.85	.83						
61			.85	.80						
7					.52	.57				
21					.60	.59				
42					.67	.65				
56			.41		.46	.46				
70					.85	.66				
8							.48	.54		
22							.60	.55		
36							.12	.60		
50							.57	.58		
9									—	.61
23									.70	.66
37									—	.46
51									.63	.64
% Variance	12.05	12.04	26.11	30.86	6.30	6.14	5.96	6.54	4.83	4.24
Eigenvalue	3.38	3.37	7.31	8.64	1.76	1.72	1.67	1.83	1.35	1.19

Factor loadings smaller than .40 have been omitted from the table. *N* = 269 students in Phase 1 and 223 students in Phase 2

4.2.1.3 Ability to Differentiate Between Classes (ANOVA Results)

ANOVA was computed to examine the ability of the TOSRA scales to differentiate between student responses in different classrooms (calculated separately for the two phases). The ANOVA results, reported in Table 4.3, indicated that for the data collected at both Phase 1 and Phase 2, four of the five TOSRA scales could differentiate significantly between classrooms – the exception, in both cases, being the Normality of Scientists scale.

Table 4.2 Internal consistency reliability (Cronbach's alpha) results for Phase 1 and Phase 2 for each attitude scale

Scale	Number of Items	Level of Analysis	Alpha Reliability	
			Phase 1	Phase 2
Attitude to Scientific Inquiry	8	Individual	.79	.82
		Class mean	.88	.94
Enjoyment of Science Lessons	6	Individual	.93	.94
		Class mean	.95	.96
Career Interest in Science	5	Individual	.81	.81
		Class mean	.80	.86
Social Implications of Science	4	Individual	.66	.73
		Class mean	.78	.78
Normality of Scientists	4	Individual	.59	.70
		Class mean	.55	.54

Table 4.3 ANOVA results for Phase 1 and Phase 2 for each attitude scale

Scale	ANOVA Results (eta^2)	
	Phase 1	Phase 2
Attitude to Scientific Inquiry	.14**	.12*
Enjoyment of Science Lessons	.36**	.27**
Career Interest in Science	.15**	.20**
Social Implications of Science	.10*	.10*
Normality of Scientists	.08	.09

Note. *N* = The sample consisted of 269 students in Phase 1 and 223 students in Phase 2.

4.2.1.4 Discriminant Validity of the TOSRA Scales

Discriminant validity provides a means of examining the degree of overlap between the different scales of the TOSRA. The results are reported in

Table 4.4. The correlation coefficients for data collected at Phase 1, reported above the diagonal, ranged from .02 to .68. For data collected in Phase 2, reported in bold below the diagonal, the correlation coefficients ranged from .05 to .61. In all cases, the factor correlations were below .80 and therefore, according to Brown (2014), met the criteria for discriminant validity.

Table 4.4 Factor transformation matrix for Phase 1 and Phase 2

	Enjoyment of Science Lessons	Attitudes to Scientific Inquiry	Career Interest in Science	Social Implications of Science	Normality of Scientists
Enjoyment of Science Lessons	—	.34	.42	.37	.20
Attitudes to Scientific Inquiry	**.26**	—	.26	.25	.02
Career Interest in Science	**.05**	**.33**	—	.08	.11
Social Implications of Science	**.28**	**.12**	**.18**	—	.68
Normality of Scientists	**.61**	**.04**	**.56**	**.56**	—

Note. Interscale correlations for Phase 1 data are reported above the diagonal and interscale correlations for Phase 2 data are reported below the diagonal in bold.

4.2.2 Reliability and Validity of the What Is Happening in This Class? Questionnaire

The 56-item version of the WIHIC questionnaire (Aldridge et al., 1999) was used to assess students' perceptions of their science classroom learning environments. In this section evidence to support the reliability and validity of the 56-item version of the WIHIC questionnaire (Aldridge et al., 1999) is reported in terms of the factor structure (Section 4.2.1.1), internal consistency reliability (Section 0) and ANOVA results (Section 0).

4.2.2.1 Factor Structure

Principal axis factor analysis indicated that the loadings for five of the items did not fit the criteria: items 6 and 8 for the Student Cohesiveness scale, items 23 and 24 for the Involvement scale, and item 36 from the Task Orientation scale. These five items were omitted from all further analyses. The factor loadings for the remaining 52 items, reported in Table 4.5, indicated that they all loaded on their own scale at .40, or more than or less than .40 on all other scales.

Table 4.5 Factor loadings, eigenvalues and percentage of variance for samples data collected at Phase 1 and Phase 2 using the WIHIC

Item No.	Factor Loading													
	Student Cohesiveness		Teacher Support		Involvement		Investigation		Task Orientation		Cooperation		Equity	
	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
1	.65	.68												
2	.58	.56												
3	.64	.66												
4	.65	.58												
5	.54	.49												
7	.60	.58												
9			.70	.75										
10			.74	.69										
11			.75	.74										
12			.63	.56										
13			.76	.68										
14			.79	.72										
15			.72	.64										
16					.55	.79								
17					.62	.77								
18					.56	.43								
20					.61	.61								
21					.53	.50								
22					.47	.55								
25							.64	.57						
26							.57	.55						
27							.87	.71						
28							.66	.63						
29							.71	.72						
30							.75	.76						
31							.74	.80						
32							.59	.80						
33									.60	.76				
34									.76	.75				
35									.53	.55				
37									.71	.61				
38									.69	.71				
39									.72	.63				
40									.79	.69				
41											.66	.66		
42											.73	.69		
43											.53	.59		
44											.80	.72		
45											.68	.70		
46											.68	.70		
47											.58	.68		
48											.62	.45		
49													.63	.72
50													.79	.71
51													.79	.77
52													.83	.67
53													.76	.83
54													.80	.77
55													.55	.76
56													.68	.78
% Variance	3.91	3.17	7.97	4.12	6.91	3.36	2.84	32.05	5.56	5.16	3.91	5.79	28.55	6.55
Eigen-value	1.96	1.56	3.98	2.06	3.46	1.68	1.42	16.02	2.78	2.58	1.96	2.90	14.27	3.27

For data collected at Phase 1, the percentage of variance ranged from 2.84 to 28.55, with a total percentage variance of 59.65%. The eigenvalues for this dataset were all greater than one, ranging from 1.42 to 14.27. Regarding data collected at Phase 2, the percentage of variance ranged from 3.17 to 32.05, with a total percentage variance of 60.20%. The eigenvalues for data collected at Phase 2 were also greater than one, ranging from 1.56 to 16.02. These eigenvalues all met Kaiser's (1960) cut-off.

4.2.2.2 Internal Consistency Reliability for the WIHIC Questionnaire

Cronbach alpha's coefficients, used as an index scale of internal consistency, are reported in Table 4.6. For data collected during Phase 1, Cronbach's alpha coefficients for different scales of the WIHIC ranged from .79 to .92 with the individual as the unit of analysis and from .84 to .93 with the class mean as the unit of analysis. Regarding data collected at Phase 2, Cronbach's alpha coefficients ranged from .79 to .93 with the individual as the unit of analysis and from .84 to .93 with the class mean as the unit of analysis. These coefficients satisfied the cut-off recommended by Yusoff (2012) and Schmitt (1996).

Table 4.6 Internal consistency reliability (Cronbach's alpha) results for data collected at Phase 1 and Phase 2 for each WIHIC scale

Scale	Number of Items	Level of Analysis	Alpha Reliability	
			Phase 1	Phase 2
Student Cohesiveness	6	Individual	.79	.79
		Class mean	.84	.84
Teacher Support	7	Individual	.88	.88
		Class mean	.86	.86
Involvement	6	Individual	.86	.86
		Class mean	.89	.86
Investigation	8	Individual	.90	.90
		Class mean	.86	.88
Task Orientation	7	Individual	.86	.86
		Class mean	.92	.92
Cooperation	8	Individual	.89	.89
		Class mean	.90	.90
Equity	8	Individual	.92	.92
		Class mean	.93	.93

Note. The sample consisted of 269 students in Phase 1 and 223 students in Phase 2.

4.2.2.3 Ability to Differentiate Between Classes (ANOVA Results)

ANOVA was computed to examine the ability of each WIHIC scale to differentiate between student responses in different classrooms (calculated separately for the two phases). The results, reported in Table 4.7, indicated that for the data collected during Phase 1 all seven WIHIC scales could differentiate significantly ($p < .05$) between classrooms. For data collected at Phase 2, six of the seven scales were able to differentiate significantly ($p < .05$) between classrooms, the exception being the Investigation scale.

Table 4.7 ANOVA results for data collected at Phase 1 and Phase 2 for the WIHIC

Scale	ANOVA results (eta^2)	
	Phase 1	Phase 2
Student Cohesiveness	.12*	.14*
Teacher Support	.12*	.11*
Involvement	.08*	.10*
Investigation	.10*	.06
Task Orientation	.18*	.10*
Cooperation	.07*	.09*
Equity	.13*	.09*

Notes. The sample consisted of 269 students in Phase 1 and 223 students in Phase 2.
**p* < .05; ***p* < .01

4.2.2.4 Discriminant Validity of the WIHIC Scales

Discriminant validity, calculated to provide an estimate of the degree of overlap between the different scales, is reported in Table 4.8. The correlation coefficients for data collected at Phase 1, reported above the diagonal, ranged from .21 to .40. Regarding data collected in Phase 2, reported below the diagonal in bold, the correlation coefficients ranged from .16 to .43. In all cases, the factor correlations were below .80, meeting the criteria for discriminant validity, according to Brown (2014).

Table 4.8 Factor transformation matrix for Phase 1 and Phase 2

Factor	Student Cohesiveness	Teacher Support	Involvement	Investigation	Task Orientation	Cooperation	Equity
Student Cohesiveness	—	.21	.36	.32	.40	.25	.28
Teacher Support	**.33**	—	.28	.28	.33	.39	.22
Involvement	**.32**	**.31**	—	.24	.22	.31	.20
Investigation	**.40**	**.40**	**.39**	—	.22	.33	.40
Task Orientation	**.34**	**.43**	**.32**	**.32**	—	.22	.31
Cooperation	**−.41**	**.16**	**.24**	**.22**	**.27**	—	.28
Equity	**.26**	**.18**	**.39**	**.17**	**.22**	**.18**	—

Note. Interscale correlations for Phase 1 data are reported above the diagonal and interscale correlations for Phase 2 data are reported in bold below the diagonal.

4.3 Girls in Secondary School Science: Attitudes and Learning Environment Perceptions

The second research question asked:

What attitudes do girls' hold towards science, and how do they perceive the learning environment in secondary science classes?

This section provides an overview of how the girls in my sample viewed secondary school science classes in terms of their attitude towards science classes (Section 4.3.1) and their perceptions of the learning environment created in science classrooms (Section 4.3.2).

4.3.1 Attitudes towards Science

Regarding girls' attitudes towards science in secondary school classrooms, the results generated using students' responses to the TOSRA at Phase 2 (secondary school science classes) are portrayed graphically in Figure 4.1 and reported in Table 4.9. Average item means for the different TOSRA scales ranged from 2.61 to 3.75, and average item standard deviations ranged from 0.58 to 0.99. Girls rated Attitudes to Scientific Inquiry the highest ($\mu = 3.75$, $\sigma = 0.68$) and Career Interest in Science the lowest ($\mu = 2.61$, $\sigma = 0.76$).

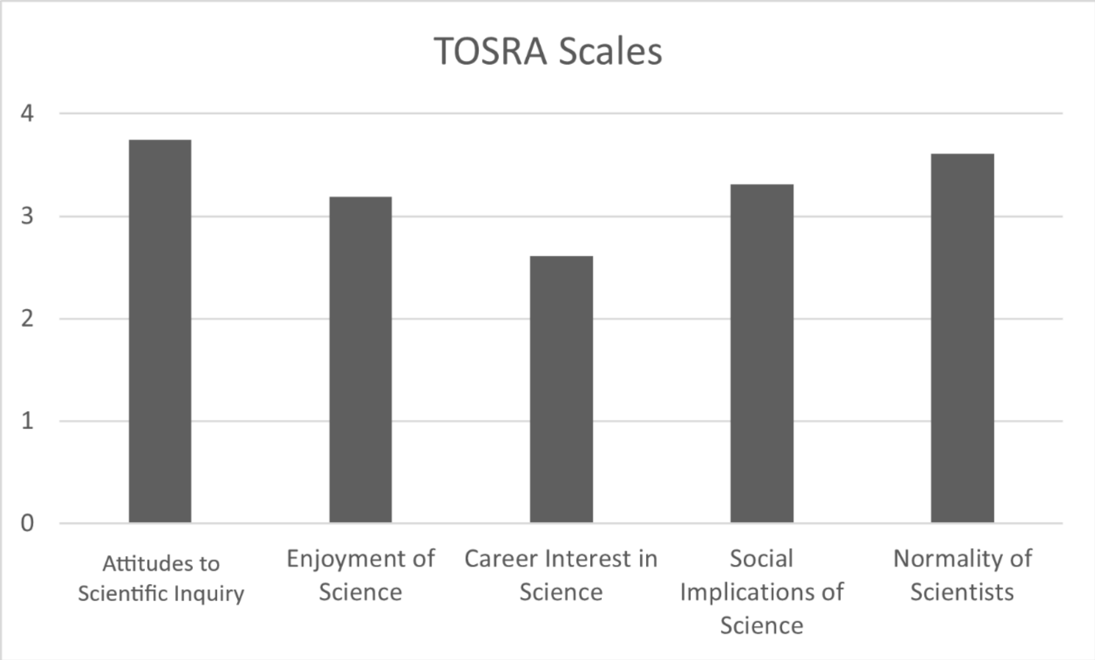

Figure 4.1 Average item means presented in a bar chart for Phase 2 TOSRA scores for girls (Phase 2 data)

Table 4.9 Average item means for Phase 2 TOSRA scores for girls

TOSRA Scale	Phase 2 Average Item Mean	Average Item Standard Deviation
Attitudes to Scientific Inquiry	3.75	0.68
Enjoyment of Science Lessons	3.19	0.99
Career Interest in Science	2.61	0.76
Social Implications of Science	3.31	0.58
Normality of Scientists	3.61	0.64

Notes. N = 130 girls from Phase 2. [a]Average item mean = Scale mean divided by the number of items in that scale.

The box and whisker plot displayed in **Error! Not a valid bookmark self-reference.** illustrates the variation of responses for each TOSRA scale. The interquartile ranges were reasonably similar (as shown by the lengths of the boxes). However, the range of responses was greatest for the Enjoyment of Science Lessons scale (as shown by the distances between the ends of the two whiskers for each boxplot), suggesting that girls have very different views about how enjoyable their science lessons are. Three TOSRA scales – Attitudes to Scientific Inquiry, Career Interest in Science and Normality of Scientists – show outliers (responses that fell more than 1.5 times the length of the box from either end of the box). Regarding Attitudes to Scientific Inquiry, these outliers suggest that although the scale had the highest average item mean, some girls responded more negatively than most other girls. For the Normality of Scientists scale, the mean score fell somewhere between ‘not sure’ and ‘agree’, and again, the outliers suggest that views were less favourable for a minority of girls. For both these scales, the outlier responses fell between ‘strongly disagree’ and ‘disagree.’ For the Career Interest in Science scale, which had the lowest average item mean (indicating that the majority of girls responded somewhere between ‘disagree’ and ‘not sure’), the outliers suggest that a minority of girls responded more favourably, between ‘agree’ and ‘strongly agree’.

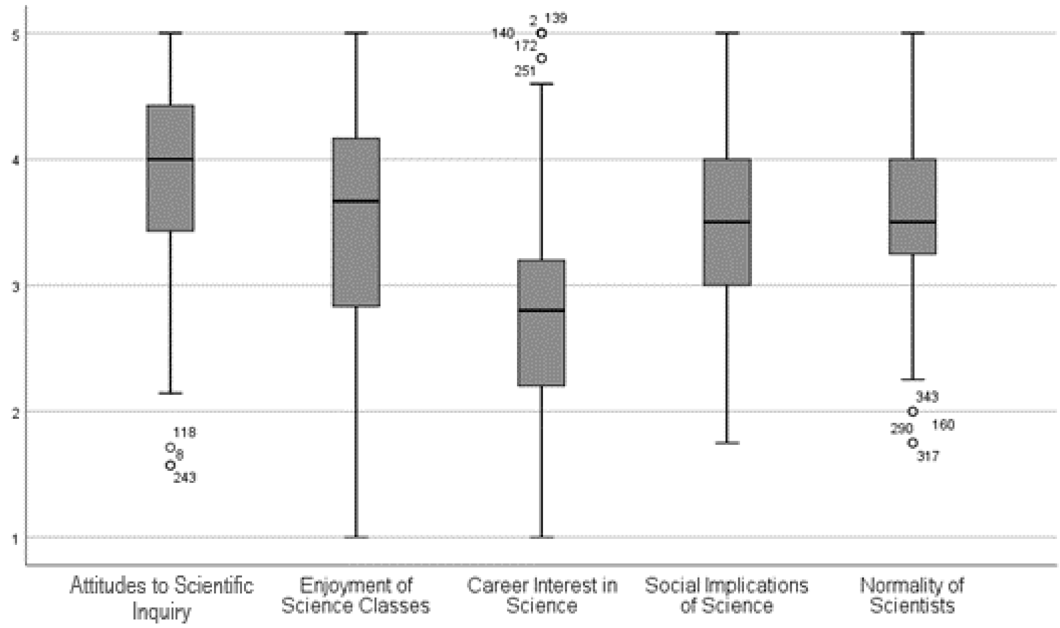

Figure 4.2 Variation of responses for each TOSRA scale

4.3.2 Learning Environment Perceptions

This section reports the responses of girls in secondary school with respect to their perceptions of the learning environment. The results, portrayed graphically in Figure 4.3 and reported in Table 4.10, indicated that, overall, average item means for different learning environment scales ranged from 3.42 to 4.40 and standard deviations ranged from 0.46 to 0.75, with students rating Student Cohesiveness the highest ($\mu = 4.40$, $\sigma = 0.46$) and Investigation the lowest ($\mu = 3.42$, $\sigma = 0.75$).

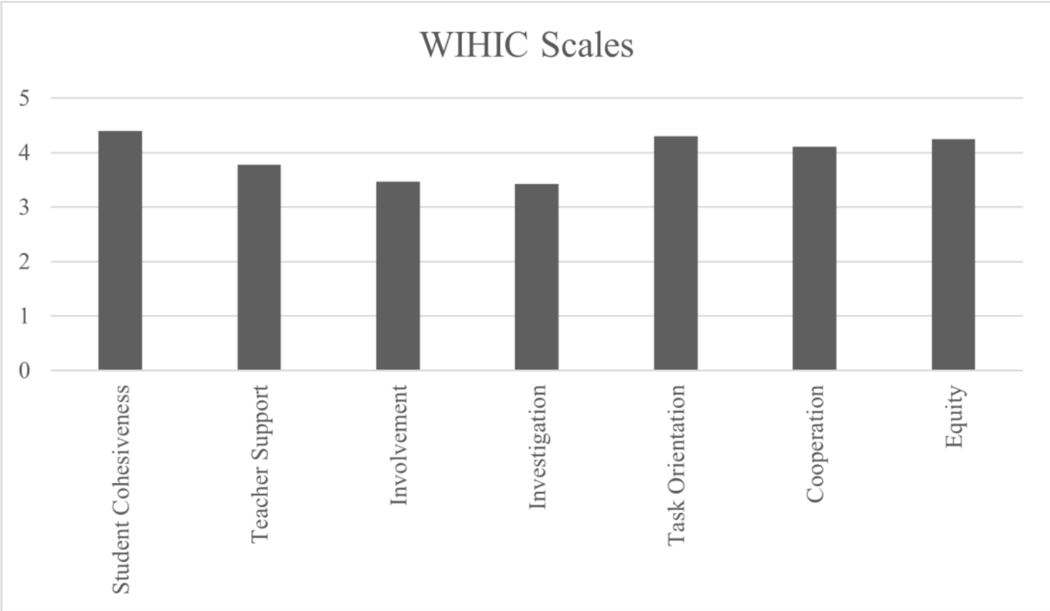

Figure 4.3 Average item means presented in a bar chart for Phase 2 WIHIC scores for girls

Table 4.10 Average item means for Phase 2 WIHIC scores for girls

WIHIC Scale	Phase 2 Average Item Mean	Average Item Standard Deviation
Student Cohesiveness	4.40	0.46
Teacher Support	3.78	0.69
Involvement	3.47	0.74
Investigation	3.42	0.75
Task Orientation	4.30	0.65
Cooperation	4.11	0.64
Equity	4.25	0.71

Notes. N = 130 girls (matched pairs) in each of Phase 1 and Phase 2. [a]Average item mean = Scale mean divided by the number of items in that scale

The box and whiskers plot, see Figure 4.4, illustrates the variation of responses for each WIHIC scale. Although the interquartile ranges were similar (as shown by the lengths of the boxes), the range of responses was greatest for the Investigations scale (as shown by the distances between the ends of the two whiskers). All but one scale, Involvement, had outliers (responses fell more than 1.5 times the length of the box from either end of the box). For Task Orientation, Cooperation and Equity, the mean fell somewhere between 'often' and 'almost always'; however, the outliers suggest that for some girls, Task Orientation, Cooperation and Equity fell between 'almost never' and 'sometimes'. This suggests that there was a less favourable learning environment for a minority of the girls. Regarding Teacher Support, the mean fell somewhere between 'sometimes' and 'often'. However, the outliers suggest that for some girls, Teacher Support fell between 'almost never' and 'seldom', revealing a less favourable learning environment for some girls.

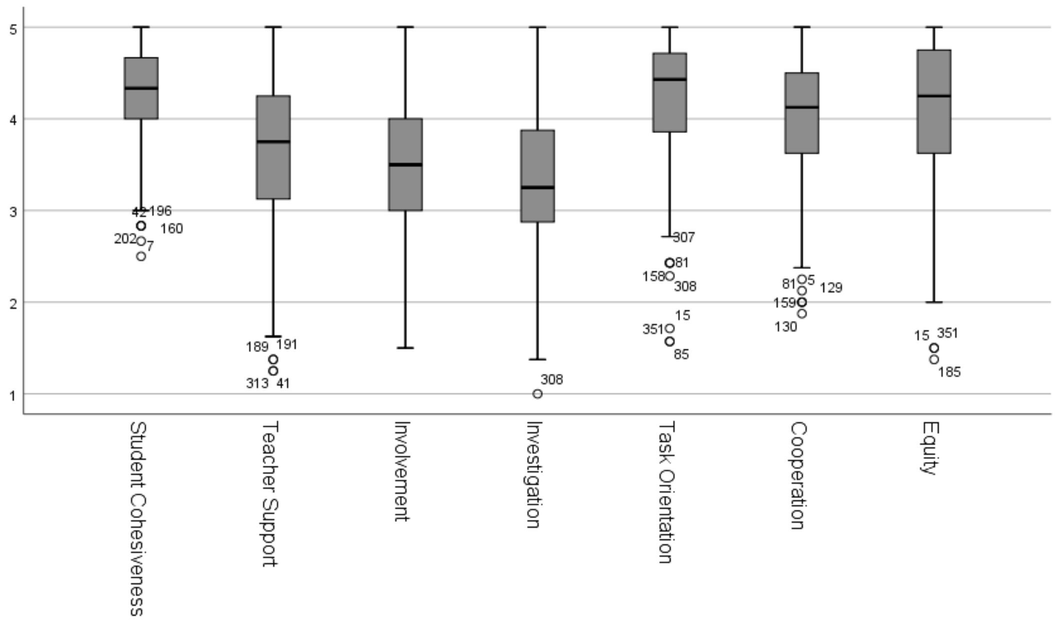

Figure 4.4 Variation of responses for each WIHIC scale

4.4 Differences for Girls in Different Settings

This section provides results of the analyses to examine whether girls in different settings varied in their attitudes towards their science classrooms and their perceptions of the learning environment. First, differences between girls' responses in co-educational and single-sex schools are reported (Section 4.4.1), and then differences between primary and secondary schools are reported (Section 4.4.2).

For research questions three and four, quantitative and qualitative data were analysed. MANOVA and effect sizes were calculated to determine whether attitudes and learning environment perceptions differed between students in co-educational and single-sex settings. The attitude and learning environment scales were used as the dependent variables in both cases, and the setting (co-educational/single-sex; primary/secondary) was used as the independent variable.

In addition to the results related to the quantitative analysis, the findings of the qualitative analysis are also reported in each section. For further information about the analyses and mixing of the quantitative and qualitative data, see Chapter 3.

4.4.1 Co-educational and Single-sex Differences

To improve understanding of whether different settings influence girls' attitudes and learning environment perceptions, the third research question asked:

Do differences exist between girls in co-educational and single-sex schools in terms of their attitudes towards science and learning environment perceptions?

Both quantitative and qualitative data were used to answer this research question. The quantitative sample involved 130 girls, 55 of whom (approximately 42%) were from a single-sex setting and 75 of whom (approximately 58%) were from a co-educational setting (see Chapter 3 for a description of the sample selection). The qualitative sample included 19 students in single-sex settings and 13 in co-educational settings.

This section reports the results of the analyses of the students' responses to the TOSRA (Section 4.4.1.1) and the WIHIC questionnaire (Section 4.4.1.2). Following this, Section 4.4.1.3 reports the findings for the analysis of the qualitative data.

4.4.1.1 Differences Between Girl's Attitudes Towards Science in Co-educational and Single-Sex Settings: Test of Science Related Attitudes Results

Students' responses to the TOSRA were used to examine differences in students' attitudes towards science in co-educational and single-sex settings. Average item means, reported in Table 4.11 and portrayed graphically in Figure 4.5, indicated that although the trends were similar for both groups, girls in a co-educational setting reported more positive attitudes compared with those in a single-sex setting, for all TOSRA scales.

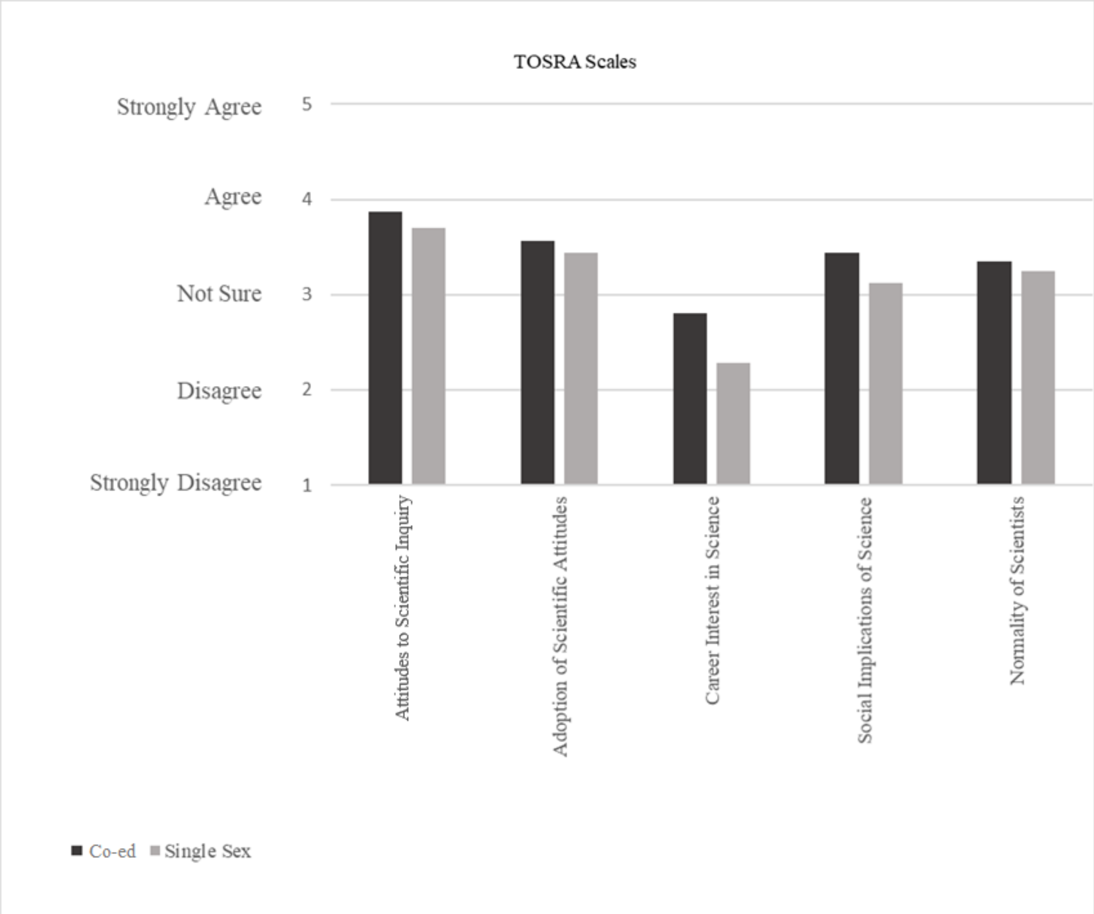

Figure 4.5 Average item means for differences in attitude scores among girls in co-educational and single-sex schools

MANOVA and effect sizes were calculated to examine the significance of the differences found between students in the different settings. First, given that the MANOVA results, in terms of Wilk's lambda, were statistically significant ($p < .05$), the univariate ANOVA results were interpreted (right-hand column of Table 4.11). These results indicated that the differences in attitude scores for girls in co-educational and single-sex settings were statistically significant ($p < .05$) for four of the five attitude scales, namely, Social Implications of Science, Normality of Scientists, Enjoyment of Science Lessons and Career Interest in Science. Further, effect sizes for those scales with a statistically significant difference ranged from .43 to 1.00. Following Cohen (1988), these effect sizes ranged from medium to large in effect. In all cases, the statistical significance differences were higher for girls in co-educational settings than for their counterparts in single-sex settings. Further, the effect sizes for these four scales indicated that the differences between students' attitudes regarding the two settings are noteworthy.

Table 4.11 Average item mean, average item standard deviation, effect size and MANOVA results for attitude differences between scores for girls attending co-educational and single-sex schools

Scale	Average Item Mean		Average Item Standard Deviation		Difference	
	Single-sex	Co-ed	Single-sex	Co-ed	Effect Size	*F*
Attitudes to Scientific Inquiry	3.66	3.82	0.63	0.71	0.24	1.93
Enjoyment of Science Lessons	2.67	3.57	0.97	0.82	1.00	32.58**
Career Interest in Science	2.33	2.82	0.74	0.71	0.68	14.91*
Social Implications of Science	3.16	3.42	0.59	0.56	0.45	6.20**
Normality of Scientists	3.46	3.73	0.62	0.64	0.43	6.06**

Notes. **p* < .05. ***p* < .01. *N* = 55 girls in single-sex schools and 75 girls in co-educational schools.

4.4.1.2 Differences Between Girls' Learning Environment Perceptions in Co-educational and Single-sex Settings: What is Happening in this Class ? Results

Students' responses to the WIHIC were used to examine differences between students' perceptions of their science learning environments in co-educational and single-sex settings. Average item means, reported in Table 4.12 and portrayed graphically in Figure 4.6, indicated that for six of the seven scales, learning environment scores were higher for girls in co-educational schools compared with girls in single-sex schools.

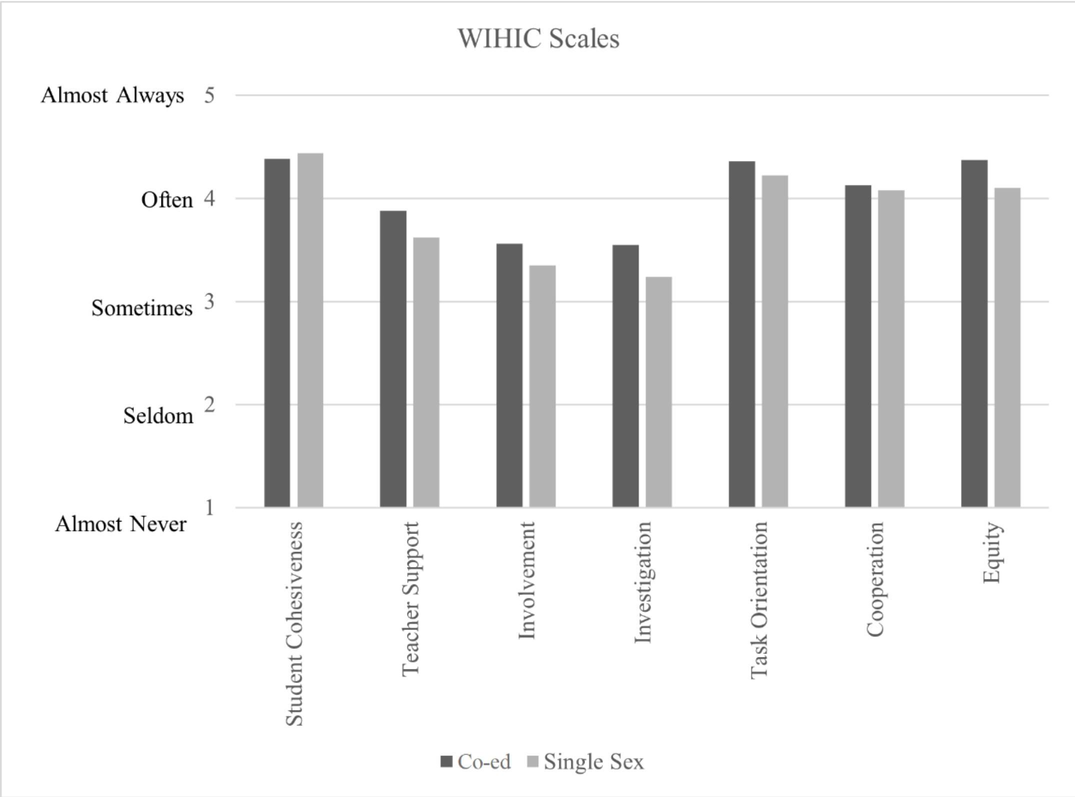

Figure 4.6 Average item means for differences in WIHIC scores among girls in co-educational and single-sex schools

Since the MANOVA results, in terms of Wilk's lambda, were statistically significant ($p < .05$), the univariate ANOVA results were interpreted (see Table 4.12). The results indicated that the differences in girls' learning environment scores between co-educational settings and single-sex settings were statistically significant ($p < .05$) for three of the seven WIHIC scales: Teacher Support, Investigation and Equity. The effect sizes for these five scales, calculated to indicate the magnitude of the differences, ranged from .38 to .42 standard deviations. Following Cohen (1988), these effect sizes were small to medium in effect. In all cases, the means were higher for girls in a co-educational setting compared with those in a single-sex setting, suggesting that these girls perceived the learning environment more favourably than did those in a single-sex setting.

Table 4.12 Average item mean, average item standard deviation, effect size and MANOVA results for learning environment differences in scores for girls between science classes in co-educational and single-sex schools

WIHIC Scale	Average Item Mean [a]		Average Item Standard Deviation		Difference	
	Single-sex	Co-ed	Single-sex	Co-ed	Effect Size	*F*
Student Cohesiveness	4.44	4.38	0.38	0.50	0.14	0.57
Teacher Support	3.62	3.90	0.70	0.66	0.41	4.53*
Involvement	3.35	3.56	0.72	0.74	0.29	2.76
Investigation	3.24	3.55	0.70	0.76	0.42	5.78**
Task Orientation	4.22	4.36	0.67	0.63	0.22	1.33
Cooperation	4.08	4.13	0.55	0.69	0.08	0.18
Equity	4.10	4.37	0.77	0.65	0.38	4.87*

Notes. *$p < .05$. **$p < .01$. $N = 55$ girls in single-sex schools and 75 girls in co-educational schools.
[a]Average item mean = Scale mean divided by the number of items in that scale.

4.4.1.3 Explaining the Differences

Thematic analysis of the qualitative information, gathered from 32 girls (19 from a single-sex setting and 13 from a co-educational setting), was performed to understand the quantitative results better. This section reports the findings that helped explain the differences between students' attitudes towards science and their perceptions of the learning environment in co-educational and single-sex settings. Two themes emerged from the qualitative analyses that helped explain these differences: confidence in class in a single-sex setting and the positive influence of boys on girls in a co-educational setting.

Confidence in Class in a Single-sex Setting

The first theme that emerged from the qualitative data analysis was related to girls' confidence in a *single-sex setting.* Although confidence was not assessed in the TOSRA, observations and interviews indicated that girls in an all-girls setting demonstrated more confidence than did their counterparts in co-educational classes, particularly with respect to sharing their understandings in class. This factor appeared to be influential in terms of how girls felt about their science classroom.

Many of the girls interviewed and observed in a single-sex setting (approximately 32%) appeared to be more confident to share in class. When asked about this observation, one of the girls noted,

> [in co-educational schools, it] affects the way you learn because you might be worried about what you look like all the time. I think being at an all-girls school is good because you don't have to worry about all things, and you can do what you want to do because you don't have to worry about what the boys would think. (Int-SS-S2-08).

Another student said, "it is just easier to talk to the girls" (Int-SS-S1-18), while another stated, "it [all-girls classroom] makes it better because we are all girls, and we understand each other" (Int-SS-S2-09). One of the girls in a co-educational setting stated "boys like science more than girls, and they know more about it and stuff" (Int-CE-S1-F-04). At the same time, another girl said that "boys and girls have different opinions towards science" (Int-CE-S1-F-11). Another girl, also in a co-education school, said that their attitudes towards science would be different in an all-girls setting. She elaborated on this, saying, "I would probably put my hand up more and answer more questions". She added later that "if it's [only] … girls, you can be more confident than if there were boys [because] you wouldn't get judged as much if you said the wrong stuff" (Int-CE-S2-F-03). These quotations helped explain why girls may not feel as confident to speak up in a co-education setting compared to girls in a single-sex environment.

Interestingly, the only scale that was more positive in a single-sex setting (quantitative data) was the scale of Student Cohesiveness. This scale measures the extent to which students know, help, and support one another. The qualitative data built on this finding and suggested that because girls felt more confident in class in a single-sex setting, they were more likely to feel more supported by one another. Therefore, the qualitative data provided a causal explanation for the Student Cohesiveness scale in the quantitative data, showing that when students feel supported, they feel more confident, which influences their perceptions of the learning environment.

Positive Influence of Boys in a Co-educational Setting

The second theme identified in the analysis was the *positive influence of boys in a co-educational setting.* This factor appeared to be influential in terms of girl's views of their science learning and experience.

It appears that, of the girls who were interviewed, approximately 31% felt that having boys in the class attributed to more positive perceptions of the learning environment. Analysis indicated that girls in both single-sex and co-educational settings felt that having boys in the class rendered (or would, in the case of girls in single-sex settings) science more fun and interesting. Many of the girls in both settings thought that boys had a positive influence for two reasons. First, boys made science more fun during investigations and secondly, boys were better at science when compared with girls. One student expressed,

> because with boys, you tend maybe to interact more, and it's more fun … But with the girls, it is like most of them are stubborn or don't want to do it, because they think it's boring … because they think that they won't use it in future life". (Int-SS-S2-16)

Another girl in a co-educational school said, "It's interesting to work with the boys" (Int-CE-S1-02), while another said, "They're funny, they have good ideas about stuff" (Int-SS-S2-21). Students expressed that through learning alongside boys in the science classroom, they gained a different understanding and could explore different perspectives. One girl from a single-sex school shared, "I think having boys in the science class would be good, cause then we can, like, mix different ideas, like, a woman's perspective and a boy's perspective" (Int-SS-S2-12). Another girl from a single-sex school expressed the difference between boys' and girls' learning and engagement in science, stating "because as girls we sort of just get on with the job, well, most of the time, whereas boys they tend to make, like, have fun, more fun of things, whereas girls honestly don't" (Int-SS-S2-19). Another girl in a co-educational setting said, "I think it [science lessons] would be a lot less entertaining [in an only girl's setting] (Int-CE-S2-F-10).

Conversely, one of the female student in a co-educational school felt that girls were more positive about science in a co-education school. She felt that “the boys make them [the girls] feel more comfortable” (Int-CE-S1-F-22) and that boys made it positive because “there are male scientists that they [the girls] can look up to during science” (Int-CE-S1-F-22). Further to this, another girl from a co-education school shared that in science classes, they are “more comfortable around guys than around girls” (Int-CES2-02) and that science would be very different in an all-girls classroom because “girls have so much drama” (Int-CES2-02).

The findings in this second theme, coupled with the quantitative results, indicated that girls in co-educational settings generally view the learning environment more positively and hold more favourable attitudes towards science.

4.4.2 Primary and Secondary School Differences

The fourth research question sought to investigate primary and secondary school differences and asked:

Do girls’ perceptions of the learning environment and their attitudes differ between primary and secondary school settings?

Both quantitative and qualitative data were used to help answer this research question. The data collection involved two phases. First, data were collected from a sample that involved 130 Year 8 students in their first month of secondary school who were asked to provide a retrospective view of their perceptions of their primary school science classrooms. Second, eight months into secondary school, the same 130 students were asked to provide their opinions of their secondary science classrooms. The sample for the qualitative data collection included 32 students.

In this section, analyses related to the students’ responses to the TOSRA (Section 4.4.2.1) and the WIHIC questionnaire (Section 4.4.2.2) are reported. Following this, Section 4.4.2.3 reports the findings for the analysis of the qualitative data.

4.4.2.1 Primary and Secondary School Differences: Attitudes

This section reports the primary and secondary school differences between students' attitudes towards science using the TOSRA data. The average item means for different attitude scales are portrayed graphically in Figure 4.7 and reported in Table 4.13. These results indicated that, for two of the five TOSRA scales (Career Interest in Science and Normality of Scientists), girls' attitudes towards science improved, with more positive responses in Phase 2 (secondary school) than in Phase 1 (primary school). For the remaining TOSRA scales, girls' attitudes deteriorated over time, with more positive responses in Phase 1 (primary school) than in Phase 2 (secondary school).

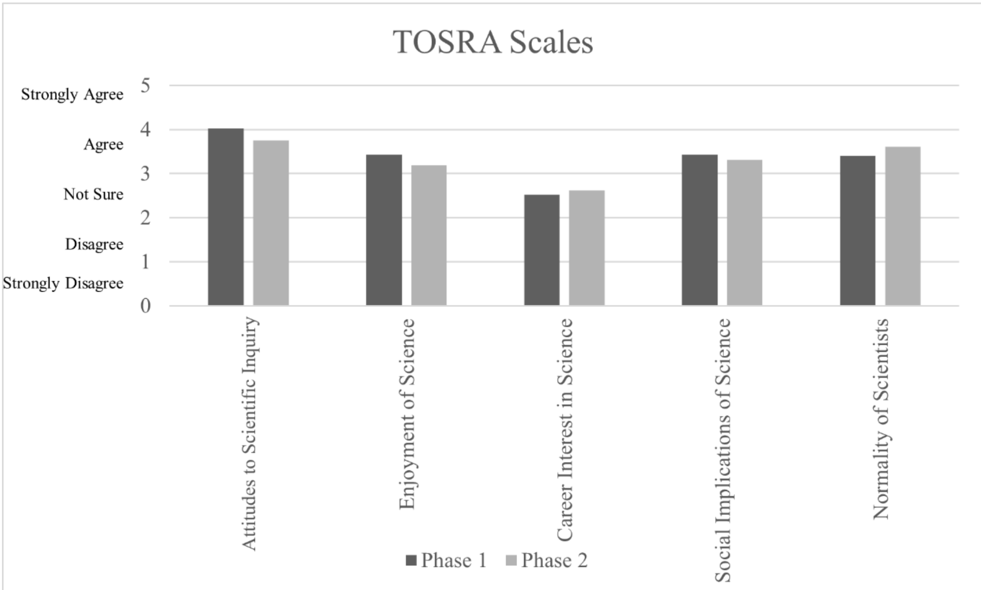

Figure 4.7 Average item means for differences in attitudes between Phase 1 and Phase 2 TOSRA scores

MANOVA and effect sizes were calculated to examine the differences further. First, the univariate ANOVA results were interpreted because the MANOVA results, in terms of Wilk's lambda, were statistically significant ($p < .05$). These results, reported in the right-hand column of Table 4.13, indicated that the differences in scores were statistically significant ($p < .05$) for three of the five TOSRA scales: Attitude to

Scientific Inquiry, Enjoyment of Science Lessons and Normality of Scientists. For the Normality of Scientist scale, girls scored higher in Phase 2, suggesting that their views regarding this scale were more positive than found in Phase 1 (views of primary school). For the remaining two scales, Attitude to Scientific Inquiry and Enjoyment of Science Lessons, the girls' responses dropped in Phase 2, suggesting that their attitudes were less positive in secondary school. The effect sizes, reported in Table 4.13, calculated to indicate the magnitude of the differences, ranged from .24 to .45 standard deviations for the three scales, with a statistically significant ($p < .05$) difference. Following Cohen (1988), these effect sizes were small to medium in effect.

Table 4.13 Average item mean, average item standard deviation, effect size and MANOVA results for differences between Phase 1 and Phase 2 scores for girls

Scale	Average Item Mean[a]		Average Item Standard Deviation		Difference	
	Phase 1	Phase 2	Phase 1	Phase 2	Effect Size	*F*
Attitudes to Scientific Inquiry	4.03	3.75	0.57	0.68	0.45	13.23**
Enjoyment of Science Lessons	3.43	3.19	0.98	0.99	0.24	3.87*
Career Interest in Science	2.52	2.61	0.76	0.76	0.12	0.95
Social Implications of Science	3.43	3.31	0.56	0.58	0.21	3.28
Normality of Scientists	3.41	3.61	0.56	0.64	0.33	7.41**

Notes. *$p < .05$. **$p < .01$. N = 130 girls (matched pairs) in each of Phase 1 and Phase 2. [a]Average item mean = Scale mean divided by the number of items in that scale.

4.4.2.2 Primary and Secondary School Differences: Learning Environment Perceptions

This section reports differences in the learning environment perceptions of girls between primary and secondary school settings (data collected in Phases 1 and 2 of the study). A graphic representation of the average item means for the different WIHIC scales is portrayed in

. The average item means for different WIHIC scales, reported in Table 4.14, indicated that for all seven WIHIC scales, students scored higher for Phase 2 when compared with Phase 1, suggesting that they viewed the learning environment more positively in secondary school classes.

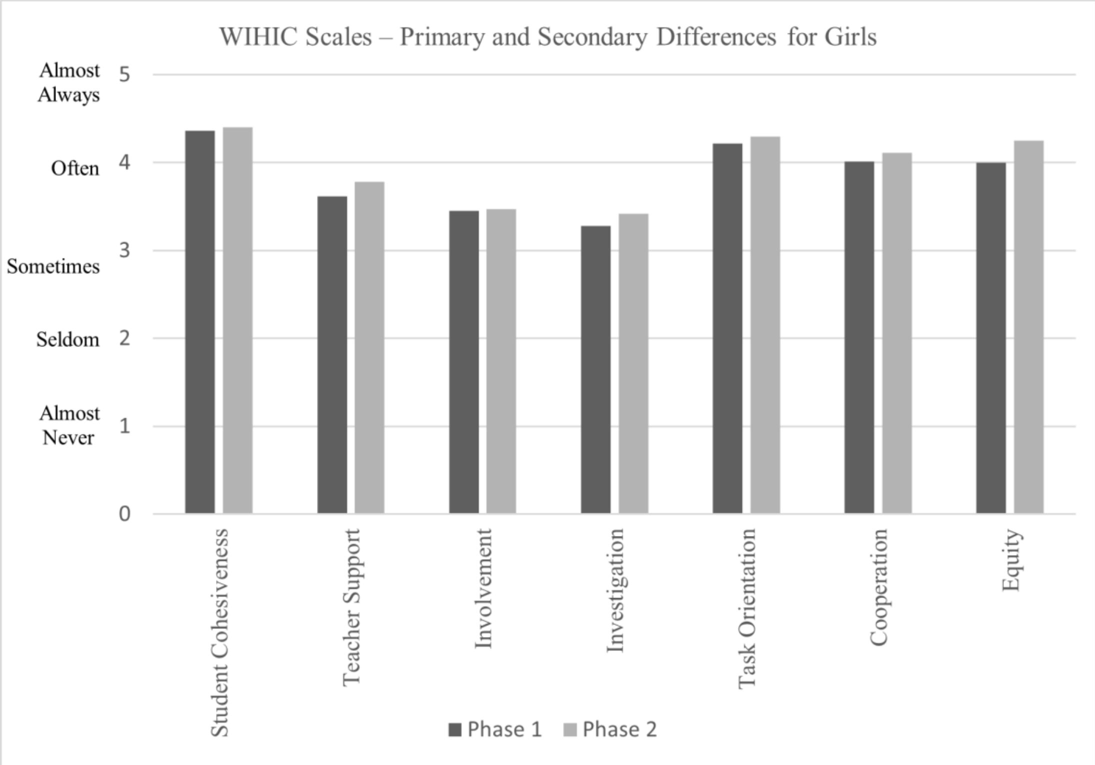

Figure 4.8 Average item means for differences in learning environment perceptions between Phase 1 and Phase 2 WIHIC scores for girls

The MANOVA results and effect sizes were used to examine the differences further. First, MANOVA was used to determine whether these differences were statistically significant ($p < .01$). Because the MANOVA results, in terms of Wilk's lambda, were statistically significant ($p < .01$), secondly, the univariate ANOVA results were interpreted (see right-hand column of Table 4.14). The ANOVA results showed that the differences in learning environment scores were statistically significant ($p < 0.05$) for only one of the seven learning environment scales, namely, Equity. For this scale, the score for Phase 1 (views of the primary school) was lower compared with the Phase 2 score (views of secondary school), suggesting that the perceptions of the learning environment were more favourable in Phase 2. The effect size for this scale, calculated to indicate the magnitude of the difference, was .33 standard deviations. Following Cohen (1988), this effect size is medium in effect.

Table 4.14 Average item mean, average item standard deviation, effect size and MANOVA results for differences between girls' Phase 1 and Phase 2 scores

Learning Environment Scale	Average Item Mean[a]		Average Item Standard Deviation		Difference	
	Phase 1	Phase 2	Phase 1	Phase 2	Effect Size	*F*
Student Cohesiveness	4.36	4.40	0.47	0.46	0.09	0.49
Teacher Support	3.62	3.78	0.81	0.69	0.21	2.78
Involvement	3.45	3.47	0.69	0.74	0.03	0.06
Investigation	3.28	3.42	0.78	0.75	0.18	2.09
Task Orientation	4.22	4.30	0.67	0.65	0.12	0.89
Cooperation	4.01	4.11	0.67	0.64	0.15	1.47
Equity	4.00	4.25	0.82	0.71	0.33	6.97**

Notes. **p* < .05. ***p* < .01. *N* = 130 girls (matched pairs) in each of Phase 1 and Phase 2. [a]Average item mean = Scale mean divided by the number of items in that scale.

4.4.2.3 Explaining the Primary and Secondary School Differences: Qualitative Results

The qualitative information gathered from 32 students was analysed to help understand the quantitative results better. Analysis of the data identified three major themes that helped to explain the differences between Phase 1 (primary school views) and Phase 2 (secondary school views) data, these being the passion and knowledge of the teacher, hands-on investigation and access to scientific laboratories, and normality of scientists.

Passion and Knowledge of the Teacher

The first theme, *passion and knowledge of the teacher*, involves two interrelated subthemes: the *passion of the teacher* (which refers to the teacher's interest in and passion towards teaching science) and the *knowledge of the teacher* (which refers to the specialist scientific and pedagogical knowledge of the teacher). Both subthemes appeared to influence students' perceptions of the learning environment and their attitudes towards science when comparing primary and secondary schools.

It appears that for many of the students (approximately 74%), the way that the teacher approached science teaching was an important factor. Analysis indicated that if a teacher was passionate about teaching science, students were more likely to hold more positive perceptions about their science lessons. When asked whether the teacher made a significant difference in how they felt about science, most students agreed that the teacher made a difference and referred to the teacher's interest in and/or passion for science. For example, one student expressed that "if you have got a boring teacher, you are not going to like the subject or go there [science lessons] very much" (Int-CE-S2-F-17). The teacher's enthusiasm in teaching science was something that many students noted. One student said, "if you didn't have a teacher that was enthusiastic towards science, or a certain area in science, I find it's probably a bit boring for the students as well" (Int-CE-S2-F-11). Another student shared, "It's hard to get interested if the teacher isn't interested" (Int-SS-S2-14), and another said that "the teacher that I have [is the deciding factor] as to whether I like it [science lessons] or not" (Int-SS-S2-06).

The results also indicated that these students felt their secondary school science teachers were more passionate than their primary school teachers. One student expressed that the teacher had a significant impact because "the teachers [in secondary school] are a lot more passionate about it [science] and you can see it" (int-SS-S1-19). While another student shared, "he's really enthusiastic about it, and it kind of rubs off on the class" (Int-CE-S2-F10). To conclude, this evidence suggests that the teachers' approach to their science teaching had a significant impact on how students felt about learning science.

The second subtheme relates to the teachers' knowledge. The results indicated that students felt that their secondary school teachers had more scientific and pedagogical expertise than did their primary school teachers. For example, one student shared that they enjoyed science more in secondary school "because you know you have got a strong theory" (Int-CE-S1-F-22). Another student shared that "the teachers [in secondary school] are a lot more knowledgeable than the primary school teacher was" (Int-SS-S1-14). It was interesting to note that students felt that this factor influenced their own interest in science. Another student shared that she enjoyed the secondary science classes more than the primary school science classes "because of how they [specialist secondary science teacher] teach". She went on to say, "I have a really good science teacher this year [secondary school]. I've learned so much and so many new things" (Int-SS-S2-19). To conclude, this evidence suggests that students felt that their secondary science teacher's specialist knowledge contributed positively to how they felt about learning science and why they felt more positively about learning science at the secondary level.

These qualitative results supported the quantitative findings. For example, although not statistically significant, student learning environment scores for Teacher Support were more positive in secondary school when compared with primary school. Therefore, both the quantitative and qualitative data indicated that the teachers' passion for and knowledge of science influenced the girls' attitudes towards science and their perceptions of the learning environment.

Hands-on Investigation and Access to Scientific Laboratories

The second theme, *hands-on investigation and access to scientific laboratories,* also involves two interrelated subthemes: *involvement in investigations* and *access to scientific laboratories*. Both factors appeared to be influential in terms of girls' views of their science learning.

The first, *involvement in investigations,* is related to how the girls' learned in their science classroom. Many of the girls (approximately 79%) indicated that there were more opportunities for *hands-on investigation* in the secondary science classroom compared with the primary science classroom. In fact, for nearly all the girls, experiments carried out at secondary school were commonly referred to as one of the favourite aspects of science lessons. One student expressed, "the experiments [in secondary school] are always fun … because you get to do it yourself and discover it yourself. If it goes wrong, you can find out why" (Int-CE-S2-F-11). Another student said, "I think I learn more in experiments because it draws your attention more" (Int-CE-S2-F-11). She went on to say, "I think the whole class gets a bit more excited and pays more attention when there's a fun activity or an experiment" (Int-CE-S2-F-11). Another student shared that "we do more hands-on stuff here [in secondary school] than we did in primary school " and that they enjoy it more because of "the experiments" (Int-CE-S1-F-04) It also appears that learning through experimentation rendered learning science in the secondary setting preferable. These findings indicated that the increased opportunity for hands-on investigations might have influenced how students felt about their science learning. Another student shared that one of the biggest reasons they were enjoying science more in secondary school was because "of more experiments and just the fact you can do bigger and bigger experiments". (Int-CE-S1-F-09).

The second subtheme, *access to scientific laboratories*, refers to the physical surroundings in the science classroom. Many of the girls attributed the increase in hands-on investigations to having access to scientific laboratories in the secondary science classroom, which was not the case in the general classroom in primary school which did not contain laboratory equipment. The increased access to science laboratories at the secondary level provided more opportunities for investigations. For example, one student shared, "I like the facilities. They're really nice here [secondary school]. The labs are nice, [it] makes you feel important, and so you want to be more involved. I like the practicals. They [secondary school] have access to resources" (Int-CE-S2-F-10). Another student said they enjoy science more in secondary school because "of experiments" [Int-CE-S1-F-02]. Another shared that they liked secondary school more than primary school "because of the science lab, the science lab is more hands-on" (Int-SS-S1-14). Finally, another student shared that they feel more positive in secondary school compared to primary school "because we did it [science] in a classroom in primary, it was just an ordinary classroom and [the school] didn't have a science lab. I had never seen a lab before until I came here [secondary school]" (Int-SS-S1-18). These findings, coupled with the quantitative results, suggest that having access to secondary school scientific laboratories allowed for more investigation opportunities. It would appear that this access helped to explain their increased enjoyment of science lessons in secondary school.

These qualitative results supported the quantitative findings and helped to provide causal explanations for them. For example, although not statistically significant, student scores for the WIHIC scale Investigation were more positive for secondary school than primary school. These findings, coupled with the quantitative findings, suggest that the increase in hands-on investigation and access may help explain quantitative differences in students' attitudes towards science and their perceptions of the learning environment.

Normality of Scientists

The third theme, *Normality of Scientists*, refers to girls' views of scientists changing over the first year in secondary school. Based on the interviews, it appears that in most cases, by the end of the first year of high school, girls viewed scientists as normal people, as opposed to predominantly male.

During interviews related to their primary school experience, the girls generally described scientists as male, wearing a lab coat and having crazy hair. For example, one student expressed that the first image that popped into her head was of "Einstein" wearing "a lab coat and glasses" (Int-CE-S1-F-22). Another girl shared that their primary school image of a scientist "was always someone like really nerdy and dorky, with big glasses (Int-SS-S1-19) and another girl shared that their image was of "crazy people" (Int-SS-S1-16). Interviews held with students after participating in secondary school for eight months demonstrated that they were aware of the change in their views. For example, one student explained, "I used to think that … scientists were always males for some reason" (Int-CE-S1-F-22). Another student shared, "teachers can be scientists" (Int-SS-S2-F-06). Another girl shared that "I now think of it [scientist] like an everyday person, who just like enjoys learning science (Int-SS-S1-19) and another shared "first of all it wouldn't have the crazy hair!" (Int-SS-S1-16). These findings, coupled with the quantitative results, suggested that students' perceptions of scientists were more positive in secondary school than primary school.

The qualitative results supported the quantitative findings and helped to provide causal explanations concerning the Normality of Scientists scale from the TOSRA. The quantitative data indicated that students in secondary schools were more likely to perceive scientists as ordinary people than they had been in primary school.

4.5 Differences for Girls and Boys: Attitudes and Learning Environment

This section reports the results for the fifth research question, which asked:

Do differences exist between girls and boys in secondary school in terms of their attitudes towards secondary school science classes and their perceptions of the learning environment?

This research question sought to understand sex differences in terms of students' attitudes towards science and perceptions of the learning environment. Both quantitative and qualitative data were used to answer this research question. Regarding the quantitative data, MANOVA and effect sizes (using data collected during Phase 2) were calculated. The sample for the quantitative analyses involved 149 secondary science students, of whom 74 were boys and 75 were girls. Since boys and girls were not found in equal numbers in every class, the within-class gender mean was used to provide a matched pair of means, one within-class mean for girls and one within-class mean for boys.

In this section, first, sex differences in responses to the TOSRA are reported (Section 4.5.1.1) and second, sex differences in responses to the WIHIC questionnaire are reported (Section 4.5.1.2).

4.5.1.1 Sex Differences in Attitudes: TOSRA Results

As a first step, the average item means for the TOSRA scales were calculated. The results, portrayed graphically in **Error! Reference source not found.** and reported in Table 4.15, indicated that for two of the five TOSRA scales (Attitudes to Scientific Inquiry and Normality of Scientists), girls responded more favourably than boys. Boys reported more positive attitudes than girls did for the remaining three scales (Social Implications of Science, Enjoyment of Science Lessons and Career Interest in Science).

The MANOVA involved student sex as the independent variable and the TOSRA scales as the dependent variable. In terms of Wilk's lambda, the results were not statistically significant; however, the univariate ANOVA results were still interpreted (reported in the right-hand column of Table 4.15). As expected, these results indicated none of the TOSRA scales demonstrated a statistical significance in the differences in attitude scores between boys and girls.

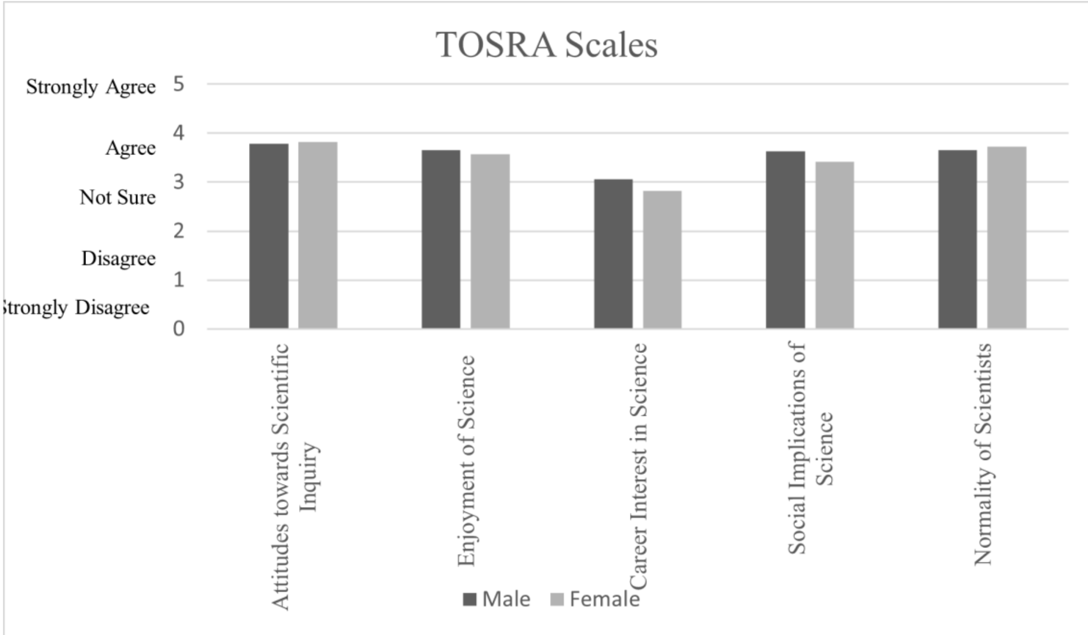

Figure 4.9 Average item means for sex differences between Phase 1 and Phase 2 TOSRA scores

Table 4.15 Average item mean, average item standard deviation, effect size and MANOVA results for differences between scores for boys and girls in science classes in co-educational schools using the within-class gender mean

Scale	Average Item Mean [a]		Average Item Standard Deviation		Difference	
	Boys	Girls	Boys	Girls	Effect Size	*F*
Attitudes to Scientific Inquiry	3.79	3.82	0.67	0.71	0.04	0.10
Enjoyment of Science Lessons	3.65	3.57	1.03	0.82	0.09	0.26
Career Interest in Science	3.06	2.82	0.83	0.71	0.31	3.60
Social Implications of Science	3.63	3.42	0.81	0.56	0.30	3.53
Normality of Scientists	3.65	3.73	0.59	0.64	0.13	0.26

Notes. **p* < .05. ***p* < .01. *N* = 74 boys and 75 girls attending co-educational schools in 9 classes.
[a]Average item mean = Scale mean divided by the number of items in that scale.

4.5.1.2 Sex Differences in Learning Environment Perceptions: ? Results

The WIHIC questionnaire was used to assess student's perceptions of the learning environment. As a first step, the average item means for different WIHIC scales were used to reveal the trends. The results, portrayed graphically in Figure 4.10 and reported in Table 4.16, suggested that for all seven scales, students' scores were higher for girls than for boys.

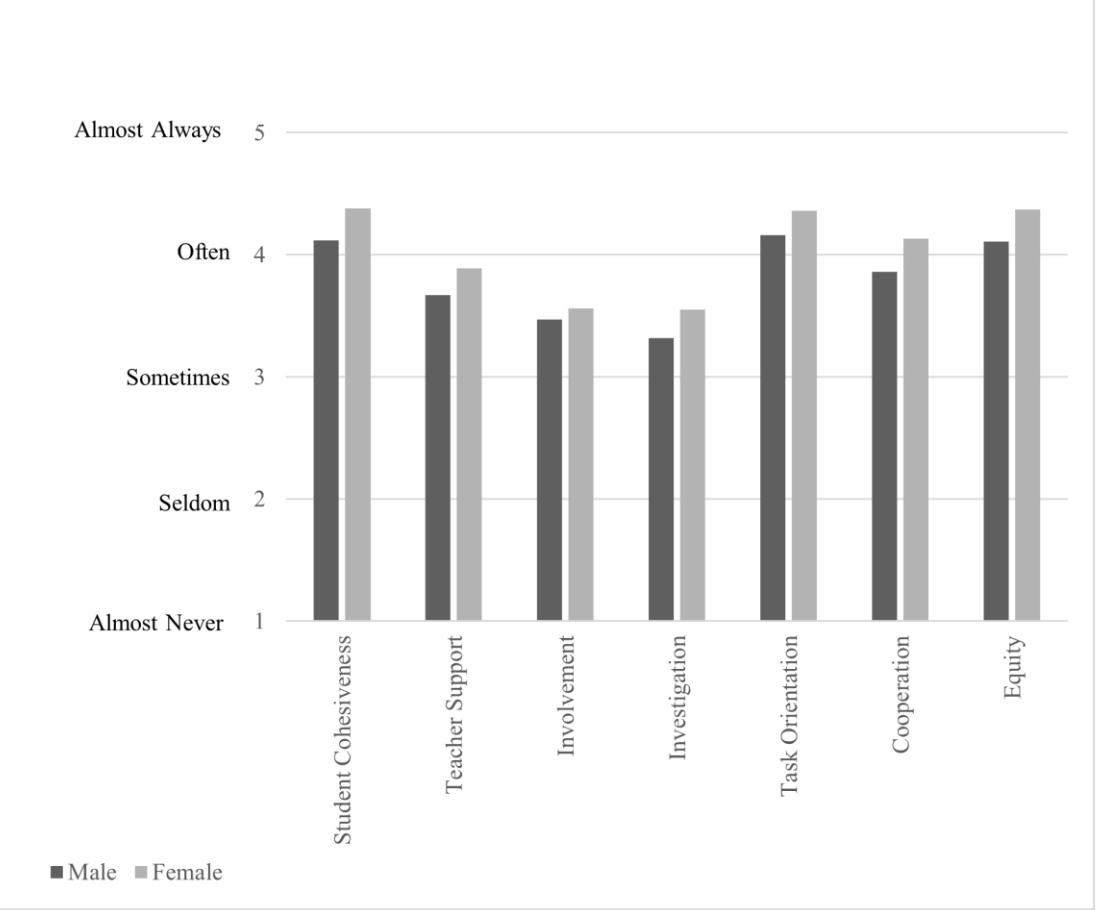

Figure 4.10 Average item means for sex differences from Phase 1 and Phase 2 for each WIHIC Scale

The MANOVA results, in terms of Wilk's lambda, were statistically significant ($p < .05$); therefore, the univariate ANOVA results were interpreted. The ANOVA results, reported in Table 4.16, indicated that the differences in learning environment scores for girls and boys were statistically significant ($p < .05$) for five of the seven WIHIC scales: Student Cohesiveness, Teacher Support, Task Orientation, Cooperation and Equity. The effect sizes for these five scales, calculated to indicate the magnitude of the differences and reported in Table 4.16, ranged from .31 to .40 standard deviations. Following Cohen (1988), these effect sizes were medium in effect.

Table 4.16 Average item mean, average item standard deviation, effect size and MANOVA results for differences between scores for girls and boys attending co-educational schools using the within-class gender mean

Scale	Average Item Mean[a]		Average Item Standard Deviation		Difference	
	Boys	Girls	Boys	Girls	Effect Size	*F*
Student Cohesiveness	4.12	4.38	0.56	0.50	0.39	5.76*
Teacher Support	3.67	3.89	0.66	0.66	0.32	3.91*
Involvement	3.47	3.56	0.68	0.74	0.13	0.62
Investigation	3.32	3.55	0.69	0.76	0.31	3.52
Task Orientation	4.16	4.36	0.59	0.63	0.31	3.69*
Cooperation	3.86	4.13	0.66	0.69	0.40	5.97*
Equity	4.11	4.37	0.68	0.65	0.40	5.82*

Notes. $*p < .05$. $**p < .01$. $N = 74$ boys and 75 girls attending co-educational schools in 9 classes.
[a]Average item mean = Scale mean divided by the number of items in that scale.

4.5.2 Explaining the Sex Differences

In this section, the results related to the analysis of the qualitative information used to help explain sex differences concerning students' learning environment perceptions and attitudes are reported. Three major themes emerged: boys are more interested, able and career-driven in science; girls are more interested in the learning environment in science; and the media plays a role in the formation of scientific stereotypes.

The sample for the qualitative analyses involved 20 students drawn from 8 secondary schools. The total number of boys in this sample was 10, and the total sample of girls in this sample was 10, therefore providing an even spread of gender.

4.5.2.1 Boys are more interested, able and career-driven in science

The first theme, *boys are more interested, able and career driven in science*, helped explain sex differences in attitudes towards science and learning environment perceptions.

For approximately 24% of the students interviewed, boys were viewed as better at science than girls. This perception appeared to hold for both boys and girls. For example, a boy (who shared similar views to the others in this group) said, “Well, in our class, I feel that boys are a bit better [at science] than the girls” (Int-CE-S1-M-10). Analysis indicated that this perception might have influenced how students (boys and girls) felt about science and their scientific abilities. For example, one of the girls who felt that boys were better at science explained, “[I think] boys like science more than girls and they know more about it and stuff” (Int-CE-S1-F-04).

The results also indicated that approximately 36% of the students felt that boys were more likely to undertake a career in science than girls were. One girl shared “because girls aren’t really [scientists] … more boys are scientists” (Int-CE-S2-03). Another girl said, “I don’t exactly know lots of female scientists, but I have seen … mostly men scientists. They [males] might be more driven to it. It might interest them more, [be]cause, maybe that’s just one of the more ... male-type jobs” (Int-SS-S2-06). When discussing careers in science among sexes, another girl mentioned, “I feel that more astronauts are boys … most of the time, astronauts are mostly boys that go out there [to space], and you hardly see any girls. They [boys] are better at maths than girls, ’cause … there’s a study that’s proven that they’re better at math than girls” (Int-SS-S2-15). One boy talked about his perceptions of girl and boy scientists, stating, “there’s still more male ones [scientists] I think … Before it was all male scientists, and I guess it is kind of continuing like that now … maybe most girls aren’t interested in it” (Int-CE-S1-M-03). Meanwhile, a girl said that boys were better at science than girls was because “they end up doing science” (Int-CE-S1-F-15). Finally, another girl shared how “boys generally become scientists over girls [because] boys like science more than girls and they know more about it” (Int-CE-S1-F-04).

The findings related to the perception that boys are more interested, able and career-driven in science could help explain the differences between boys’ and girls’ responses to the survey data. For example, student scores for Career Interest in Science were more positive for boys. Although not statistically significant, boys also had more favourable scores for Social Implications of Science compared with girls. These findings, coupled with the quantitative findings, suggest that the view that boys are more interested, able and career-driven in science might have been influential in terms of students' attitudes towards science and their perceptions of the learning environment.

4.5.2.2 Girls Are More Interested in the Learning Environment in Science

The second theme, *girls are more interested in the learning environment in science,* helped explain why girls had more positive perceptions of the learning environment than their male counterparts did.

Without being directly asked about the learning environment, it appeared that it was an important factor for many girls (approximately 47%). Girls often discussed aspects of the learning environment, such as the support network they had in their class through friendships, the breadth of subject materials and the types of tasks they undertook. For example, one girl reported, "[The best thing about science is] being able to work with other students and get their opinions on things to get the one answer" (Int-SS-S2-08). Another girl said she enjoyed science because she could engage in "fun activities where you can do group work". In contrast, boys did not mention these factors in their interviews.

It would also appear that the science content was something that girls enjoyed about science classes. For example, one girl shared how "science in secondary school is a lot more interesting and a lot more in-depth". She added, "as you mature, you learn about more mature things. And I enjoy … studying medicine and that kind of thing. That's cool to learn about" (Int-SS-S2-14). During the interviews, girls often spoke about the type of tasks that they undertook. For example, one girl shared that she would enjoy science more as a subject if she were given more choice and agency, stating,

> I feel if we were offered … a little bit more of the tasks where it's of your own choice [I would enjoy science more]. We did a task recently where you choose your field of science to present an oral presentation, so I did psychiatry. (Int-SS-S2-14)

Another girl mentioned that she enjoyed science because of the independent nature of the activities, stating, "[I enjoy science because] we get to do independent work, like when we write our own prep reports after we do experiments" (Int-SS-S2-16). Another girl shared that "when I got to high school I learned about habitat, setting experiments for myself, I've used immersive stuff, and it's more visual now" (Int-SS-S1-18). Science content was not something any of the boys discussed in their interviews when asked about what they enjoyed.

These qualitative results supported the quantitative findings and helped provide causal explanations for the results reported from three scales (Student Cohesiveness, Task Orientation, and Cooperation). Girls scored higher than their male counterparts on all three scales, and the differences were statistically significant ($p < .05$). These findings, coupled with the quantitative findings, suggest that learning environment factors may have been more influential for girls when compared with boys.

4.5.2.3 The Role of Media in the Formation of Scientific Stereotypes

The third theme that emerged, *the role of media in the formation of scientific stereotypes*, was related to the role of media in the portrayal of science. The theme helped explain how media may have influenced the sex differences regarding students' views of science.

Approximately 20% of students named that the media had an influence in their portrayal of sex balances in the sciences, expressing that there are more male scientists and more career opportunities for boys. When asked why he thought of scientists as boys rather girls, one boy shared, "Well, going to like maybe some TV you always see male scientists. You do see some females, but not a lot" (Int-CE-S1-M-10). In a similar vein, a girl said, "I think there might be more male scientists because that's just what's like, all through the media and stuff because girls might generally be interested in beauty and shopping so they might follow a career in that" (Int-SS-S2-08). She added, "girls really listen to the media so much" (Int-SS-S2-08). Another girl shared, "you always see males doing science". When asked why, she said, "I think, advertising and stuff, and TV shows, they just always use males" (Int-SS-S2-20). Another girl shared that she thought boys were better at science than girls because "they're better at math and I feel like astronomists are mostly boys" (Int-SS-S2-15). Further, she stated that she got this information "from the TV and people have said it" (Int-SS-S2-15). The students indicated that the portrayal of male stereotypes in science on television affected girls in terms of their career choice. Finally, when speaking about there being more male scientists than female, another girl said, “I think there would be more males than females in some areas” and “ I think girls more go into, this is going to sound so stereotypical, like, more girly jobs” (Int-SS-S2-19). Further, one boy stated that boys were more positive about science than girls “just because of the hundreds of years of males that have done it” (Int-CE-S1-M-13). To conclude, it appears many scientific stereotypes are still in existence, which influence the way students feel about science and their scientific abilities now and into the future.

These qualitative results supported the quantitative findings, particularly regarding students’ scores for the Career Interest in Science scale of the TOSRA, for which there was a difference, with boys’ responses being more positive compared with girl’s responses. Based on the findings related to this theme, the male-dominant portrayal of scientists in the media could be influential in terms of students’ aspirations to become scientists.

4.6 Learning Environment – Outcome Relationships

The last research question sought to understand the relationships between the learning environment and students’ attitudes and achievement. This question asked:

Do relationships exist between girls’ perceptions of their science classroom environment and their:

- *attitudes towards science and*
- *science achievement?*

The sample used for this research question was 130 girls from Phase 2. Environment–attitude relationships are reported in Section 4.6.1, after which environment–achievement relationships are reported in Section 4.6.2. For both sets of results, the analyses were the same. As described in Chapter 3, simple correlation analysis (r) was used to examine the bivariate relationship between each learning environment scale and attitude scale or achievement score. Multiple regression analysis was used to explore the multivariate association between an attitude scale or achievement score and the set of seven WIHIC scales. The independent variables were the learning environment scales, and the dependent variables were the attitude scale or achievement score. Standardised regression coefficients (β) for each independent variable were used to determine the effect of each predictor (learning environment scale) on the dependent variable (attitude scale or achievement score) when all other WIHIC scales were mutually controlled.

4.6.1 Learning Environment – Attitude Relationship

This section reports the results for the simple correlation and multiple regression analyses. Table 4.17 reports the results of the analyses, which are described separately below the table for each attitude scale.

For the Social Implications scale, the simple correlation results indicated that four of the seven WIHIC scales (Teacher Support, Involvement, Investigation and Task Orientation) were positively statistically significantly ($p < .05$) related. The statistically significant correlations were all positive and ranged from .14 to .28. The multiple correlation (R) was .50, positive and statistically significant ($p < .01$). The standardised regression weights (β) were positive and statistically significant ($p < .01$) for two of the seven WIHIC scales, these being Investigation and Task Orientation.

Regarding the Normality of Scientists scale, the results of the simple correlation analysis indicated that three of the seven WIHIC scales (Involvement, Investigation and Task Orientation) were positively statistically significantly ($p < .05$) related. The statistically significant correlations were all positive and ranged from .13 to .19. The multiple correlation (R) for the learning environment scales and Normality of Scientists scale was .38, positive and statistically significant ($p > 0.01$). The standardised regression weights (β), reported in Table 4.17, show that two WIHIC scales (Social Cohesiveness and Investigation) were significantly ($p > 0.05$), positively and independently related to students' views of the Normality of Scientists.

Table 4.17 Simple correlation and multiple correlation analysis for associations between perceptions of the learning environment (WIHIC scales) and attitudes towards science (TOSRA scales)

Scale	Social Implications		Normality of Scientists		Attitudes to Scientific Inquiry		Enjoyment of Science Lessons		Career Interest in Science	
	r	β	*r*	β	*r*	β	*r*	β	*r*	β
Social Cohesiveness	.59	−.12	.09	.23*	.10	.16	.05	−.09	.03	−.15
Teacher Support	.14*	.17	.08	.10	.04	.08	.24**	.06	.14*	−.03
Involvement	.22**	.06	.13*	−.00	.10	.02	.21**	−.03	.16**	.02
Investigation	.24**	.28**	.19**	.26*	.12	.11	.28**	.26**	.27**	.31**
Task Orientation	.28**	.27**	.14*	−.03	.12	.13	.46**	.43**	.29**	.15
Collaboration	.01	−.21	.10	−.10	.08	−.07	.16**	−.13	.09	−.15
Equity	.11	−.00	.12	−.07	.03	−.02	.20**	.13	.17**	.18
Multiple correlation (*R*)	.50**		.38**		.32		.60**		.44**	
*R s*quared	.25		.14		.10		.37		.20	

In terms of the Attitudes to Scientific Inquiry scale, the results of the simple correlation analysis indicated that none of the seven WIHIC scales were statistically significantly (p < .01) related. The multiple correlation (R) for the learning environment scales was .32, which was not statistically significant. The standardised regression weights (β), reported in Table 4.17, indicated that no significant predictors of Attitudes to Scientific Inquiry.

In relation to the Enjoyment of Science Lessons scale, the simple correlation results analysis indicated that six of the seven WIHIC scales were positively and statistically significantly (p < .01) related (Teacher Support, Involvement, Investigation, Task Orientation, Collaboration and Equity). The statistically significant correlations were all positive and ranged from .16 to .46.Ie multiple correlation (R) for the learning environment scales was .60 for Enjoyment of Science Lessons and was positive and statistically significant (p > 0.01). The standardised regression weights (β), reported in Table 4.17, show that for Enjoyment of Science Lessons, two learning environment scales, Investigation and Task Orientation, were statistically significant (p < .01), and positively and independently related.

Lastly, for the Career Interest scale, the results of the simple correlation analysis indicated that five of the seven WIHIC scales were positively statistically significantly (p < .05) related (Teacher Support, Involvement, Investigation, Task Orientation and Equity). The statistically significant (p > 0.05) correlations were all positive and ranged from .14 to .29. The multiple correlation (R) for the learning environment scales was .44 for Career Interest and was positive and statistically significant (p > 0.01). The standardised regression weights (β) show that one WIHIC scale (Investigation) was an independent predictor of Career Interest in Science.

4.6.2 Learning Environment – Achievement Relationships

This section reports the simple correlations and multiple regression results for the relationships between each WIHIC scale and science achievement. The results are reported in Table 4.18.

Table 4.18 Simple correlation and multiple correlation analysis for associations between perceptions of the learning environment (WIHIC scales) and science achievement

Scale	Student Achievement	
	r	β
Social Cohesiveness	.34**	.20
Teacher Support	.29**	−.01
Involvement	.29**	.01
Investigation	.35**	.22
Task Orientation	.25*	.01
Collaboration	.25*	−.00
Equity	.32**	.14
Multiple correlation (*R*)		.44**

Notes. *$p < .05$. **$p < .01$. $N = 130$ girls (Phase 2 data).

The results of the simple correlations, reported in Table 4.18, indicate that all seven WIHIC were statistically significantly and positively correlated ($p < .05$) with science achievement. The multiple correlation (R) reported at the bottom of Table 4.18 for the set of seven WIHIC scales was positive and statistically significant ($p < .01$). This suggests a relationship between student achievement and the set of scales assessing classroom environment. The standardised regression weights (β) indicated that no WIHIC scales were significant independent predictors of science achievement.

4.7 Chapter Summary

This chapter reported the results of the analyses undertaken to address each of the six research questions. This section summarises these findings.

To provide support for the reliability and validity of the instruments when used in South Australia, the factor structure, internal consistency reliability, ability to differentiate between groups of each instrument and discriminant validity of both instruments were examined (research question 1).

For the TOSRA data, item analysis, conducted during principal axis factor analysis, found that 42 items did not fit the criteria; therefore, they were omitted from all further analyses. The final factor analysis consisted of 28 items over five TOSRA scales. All but three of these items (from the Phase 1 dataset) loaded at .40 or above. Items 9 and 37 (for the Normality of Scientists scale) did not load at .40 on their scale or any other scale. The internal consistency reliability values for individual TOSRA scales were all above 0.5, which were considered acceptable. The results of the ANOVA, computed to examine the ability of each TOSRA scale to differentiate between students in different classrooms, found that for data collected in both Phase 1 and Phase 2, four of the five TOSRA scales were able to differentiate significantly ($p < .05$) – the exception, in both cases, being the Normality of Scientists scale. The correlation coefficients for data collected in Phase 1 and Phase 2 were below .80; therefore, they met the criteria for discriminant validity, according to Brown (2014).

Regarding the WIHIC scales, item analysis indicated that all but five items, for both Phase 1 and Phase 2 data, fitted the criteria. Once these five items were removed, the remaining 51 items all loaded on their own scale at .40 or more than or less than .40 on all other scales. The internal consistency reliability for individual WIHIC scales were all above 0.5., which was considered acceptable. The ANOVA results, used to examine whether WIHIC scales could differentiate between students in different classrooms, indicated that for the Phase 1 data, all WIHIC scales were able to differentiate significantly ($p < .05$) between classrooms and for Phase 2 data, six of the seven WIHIC scales were able to differentiate significantly ($p < .05$) between classrooms (the exception being the Investigation scale). The correlation coefficients for data collected during Phase 1 and Phase 2 were below .80, and therefore they met the criteria for discriminant validity, according to Brown (2014).

Together, the results of the factor analysis and internal consistency reliability provided evidence to support the reliability and validity of both the TOSRA and WIHIC questionnaire when used during both phases. These findings helped interpret the results of subsequent research questions.

Descriptive statistics, comprising the average item mean and average item standard deviation, were used to provide an overview of secondary school girls' attitudes towards science and their perceptions of the learning environment (research question 2). The average item means for the different TOSRA scales ranged from 2.61 to 3.75, and the average item standard deviations ranged from 0.58 to 0.99. Girls rated their Attitudes to Scientific Inquiry the highest ($\mu = 3.75$, $\sigma = 0.68$) and Career Interest in Science the lowest ($\mu = 2.61$, $\sigma = 0.76$). The average item means for different WIHIC scales ranged from 3.42 to 4.40 and standard deviations ranged from 0.46 to

0.75, with students rating Student Cohesiveness the highest (μ = 4.40, σ = 0.46) and Investigation the lowest (μ = 3.42, σ = 0.75).

MANOVA and effect sizes were calculated to examine whether attitudes and learning environment perceptions were different for girls in co-educational and single-sex schools (research question 3). The results from four TOSRA scales indicated that girls in a co-educational setting had statistically significantly ($p < .05$) more favourable attitudes towards science compared with girls in a single-sex setting: Social Implications of Science (effect size = 0.45), Normality of Scientists (effect size = 0.43), Enjoyment in Science Lessons (effect size = 1.00) and Career Interest in Science (effect size = 0.68). The results for the WIHIC scales showed a similar trend, with three scales reporting a statistically significant ($p < .05$) difference. Girls in co-educational schools reported more favourable learning environment perceptions compared with girls in single-sex schools: Teacher Support (effect size = 0.41), Investigation (effect size = 0.42) and Equity (effect size = 0.38). The qualitative information, gathered to help explain these findings, suggested that girls in a co-educational setting found that having boys in the class increased their enjoyment of science lessons. Although not explicitly stated, it also appeared that having boys in the classroom might have increased girls career interest in science. Conversely, other qualitative findings indicated that girls in all-girls settings were more confident than girls in co-educational settings, particularly with respect to sharing their understandings in class.

MANOVA and effect sizes, in addition to the analyses of qualitative information, were also used to determine whether attitudes and learning environment perceptions were different for girls in primary and secondary school (research question 4). The results suggested that, for the TOSRA data, the scores were statistically significant ($p < .05$) for three of the five scales: Attitudes to Scientific Inquiry (effect size = 0.45), Enjoyment of Science Lessons (effect size = 0.24) and Normality of Scientists (effect size = 0.33). For the Normality of Scientist scale, students scored higher in Phase 2, suggesting that students' views of science were more positive in secondary school. For the Attitudes to Scientific Inquiry and Enjoyment of Science Lessons scale, students' scores dropped during Phase 2, suggesting that their attitudes were less positive in secondary school. The qualitative data supported the quantitative findings regarding Normality of Scientists and indicated sex stereotypes related to Social Implications of Science and Career Interest in Science. As mentioned previously, many girls (and some boys) expressed that they felt boys were better at science than girls and that boys were more likely to undertake a career in science.

The results suggested that, for the WIHIC data, the differences found in learning environment scores were statistically significant ($p < 0.05$) for one of the seven learning environment scales, namely Equity (effect size = 0.33). For this scale, the score in Phase 1 (views of the primary school) was lower when compared with the Phase 2 score, suggesting that the perceptions of the learning environment were more favourable in Phase 2. The qualitative data supported the quantitative findings, indicating that both boys and girls enjoyed the subject matter taught in their secondary science classes; they expressed that the breadth of subject material and various ways of learning made science more interesting. Many of the girls, compared with boys, expressed how influential the teacher was in enhancing their interest in and enjoyment of science lessons. The girls who were interviewed also expressed concern about sharing their ideas in class. Analysis indicated that this could be because girls felt, generally, boys were better at science than girls.

MANOVA and effect sizes were used to examine sex differences (research question 5). For students' attitudes towards science, the ANOVA results indicated that none of the TOSRA scales were statistically significant for differences between boys and girls. For perceptions of the learning environment, the results indicated statistically significant ($p < .05$) sex differences for five of the seven WIHIC scales: Student Cohesiveness (effect size = 0.39), Teacher Support (effect size = 0.32), Task Orientation (effect size = 0.31), Cooperation (effect size = 0.40) and Equity (effect size = 0.40). In all cases, girls reported more positive perceptions of the learning environment

Simple correlation and multiple regression analyses were used to examine whether there were relationships between girls' perceptions of the learning environment and their attitudes, and between their learning environment perceptions and achievement (research question 6). For the environment–attitude relationships, the simple correlation (r) results indicated positive and statistically significant relationships

($p < .05$) between different factors of the learning environment and all but one attitude scale (Attitude to Scientific Inquiry). For these scales, the findings suggested that a more positive learning environment is likely to improve students' attitudes in these areas. Attitudes to Scientific Inquiry was the exception since no statistically significant relationships between any of the learning environment scales were found. The results of the multiple regression analysis were statistically significant for four of the five attitude scales (the exceptions being Attitudes to Scientific Inquiry). The standardised regression coefficients (β) showed that different factors of the learning environment were independent predictors of student attitudes for all scales except Attitudes to Scientific Inquiry. These findings suggested that a more favourable classroom learning environment could promote more positive attitudes towards science for girls. Overall, the results provided strong support for associations between student attitudes and classroom environment perceptions.

Regarding the environment–achievement relationships, the simple correlation (r) results indicated a relationship between student achievement and all seven WIHIC scales. The multiple regression, used to examine the multivariate association between achievement scores and the set of seven environment scales, was also positive and statistically significant. The standardised regression coefficients (β) indicated that none of the learning environment scales contributed to a variance in achievement when all other WIHIC scales were mutually controlled. Although these findings suggest a relationship between student achievement and the set of scales assessing classroom environment, interestingly, none of the scales were independent predictors of achievement.

The next chapter concludes the thesis. It provides a discussion of these results. In addition, the chapter outlines the limitations of the present study, while making recommendations for future research. It also provides an outline of the significance of the study.

Chapter 5

DISCUSSION AND CONCLUSION

5.1 Introduction

The focus of this study was to gain a better understanding of how girls have been faring in science classrooms in different contexts with a view to improving their experience and encouraging aspirations for girls to pursue science. This study examined girls' attitudes in different contexts and the types of learning environments that might enhance those attitudes.

The study drew on the interpretivist paradigm to improve understanding of the multiple realities perceived and described by the students in their particular contexts. Using this paradigm allowed me to explore students' experiences and perceptions deeply and capture authentic student voices.

The design of this study used an explanatory sequential mixed methods design that involved three overlapping phases of data collection. The first and second phases involved collecting quantitative data, and the third phase involved gathering qualitative data to explain the quantitative findings (Caruth, 2013). In Phase 1, surveys were administered to Year 8 students in their first month of secondary school (to provide a retrospective view of their primary school science classrooms). In Phase 2, the same surveys were administered to the same students in the same classes eight months after Phase 1 (to gain their perceptions of their secondary school science classrooms). In the third phase, qualitative information was gathered to provide causal explanations for the quantitative results. The qualitative data were used to obtain more detailed, specific information and provide further depth and understanding of the research questions, as recommended by Creswell (2008).

Quantitative data were collected using two instruments. First, the TOSRA examined students' attitudes towards science. Second, the WIHIC questionnaire assessed students' perceptions of the science classroom learning environment.

The collection of qualitative data occurred in Phase 3 and involved two stages. Stage 1 immediately followed quantitative data collection. After analysis of the quantitative (Phases 1 and 2) and qualitative data (Phase 3, Stage 1), further interviews (Phase 3, Stage 2) were undertaken, particularly concerning differences found between girls in a co-educational setting versus girls found in a single-sex setting. These data were collected using semi-structured interviews with students. Semi-structured interviews involved using key questions to guide the interview and allowed the participants to explore lines of interest, as recommended by Kvale (2007).

Finally, achievement data were collected. Teachers provided an end-of-semester grade for students who participated in the surveys and a one-sentence comment regarding students' attitudes and participation in science lessons. Not all teachers provided both of these details, but those who did were asked to consider the average of the various assessments completed by the participating students in science over 20 weeks (half a year).

This chapter concludes the thesis by summarising and discussing the findings and their implications under the following headings:

- Summary and Discussion of Major Findings (Section 5.2)
- Limitations of the Study (Section 5.3)
- Summary of Recommendations (Section 5.4)
- Significance of the Study (Section 5.5)
- Concluding Remarks (Section 5.6).

5.2 Summary and Discussion of Major Findings

This section provides a summary and discussion of the major findings of this research. The section is organised according to the results of each of the research questions, as follows:

- validity and reliability of the instruments used in this study (Section 5.2.1)
- secondary school girls' attitudes towards science and their perceptions of the learning environment (Section 5.2.2)

- differences for girls in different settings, namely, co-educational and single-sex schools (Section 5.2.3)
- differences for girls in different settings, namely, primary and secondary schools (Section 5.2.4)
- sex differences in secondary school (Section 5.2.5)
- relationships between learning environment and attitudes towards science (Section 5.3.6)
- relationships between learning environment and science achievement (Section 5.3.7).

5.2.1 Validity and Reliability of the Instruments

The first research question sought to determine whether the instruments used to assess students' attitudes towards science and their perceptions of the learning environment were valid and reliable when used with students in South Australia. The analyses for this research question involved the complete dataset (including 269 secondary school students from 10 secondary schools in Phase 1 and 223 secondary school students from 10 secondary schools in Phase 2). All analyses were conducted separately for data collected during Phase 1 and Phase 2.

To provide evidence for the reliability of the instruments, the factor structure, internal consistency reliability and ability to differentiate between groups were examined. The results are summarised and discussed separately for the TOSRA (see Section 5.2.1.1) and WIHIC questionnaire (see Section 5.2.1.2).

5.2.1.1 Validity and Reliability of the Test of Science Related Attitudes

A summary of key findings for the validity and reliability of the TOSRA is provided below:

- Of the 70 items, 42 did not meet the criteria and were omitted from all further analyses.
- The modified version included 28 items that fitted the criteria for both Phase 1 and Phase 2 data.

- For data collected at Phase 1 –
    - the percentage of variance ranged from 4.83% to 26.11%, with a total percentage variance of 55.25%
    - the eigenvalues ranged from 1.35 to 7.31.
- For the data collected at Phase 2 –
    - the percentage of variance ranged from 4.24% to 30.86%, with a total percentage variance of 59.83%
    - the eigenvalues ranged from 1.80 to 4.55.
- The internal consistency reliability (Cronbach's alpha coefficient) for individual scales was as follows –
    - data collected at Phase 1 ranged from .53 to .93 with the individual as the unit of analysis and from .55 to .95 with the class mean as the unit of analysis.
    - data collected at Phase 2 ranged from .70 to .94 for the individual as the unit of analysis and from .54 to .96 for the class mean as the unit of analysis.
- For both Phase 1 and Phase 2, four of the five TOSRA scales could differentiate significantly between classrooms, the exception in both cases being the Normality of Scientists scale.
- The correlation coefficients for data collected at Phase 1, ranged from .02 to .68. The correlation coefficients for data collected in Phase 2, ranged from .05 to .61. In all cases, the factor correlations were below .80 and therefore met the criteria for discriminant validity, according to Brown (2014).

The study results provided evidence to support the reliability of the modified TOSRA when used with this sample. Despite the large number of items that did not meet the criteria for factor loadings, the eigenvalues for individual scales (for data collected during both Phase 1 and Phase 2) were all above one, thereby meeting Kaiser's (1960) recommended cut-off. Although the internal consistency reliability was relatively low for one scale (Normality of Scientists), the coefficients all were above .50, which, based on the criteria outlined by Yusoff (2012) and Schmitt (1996), is considered acceptable. The findings compare favourably with the results of other recent studies using the TOSRA both in Australia (Fraser, Aldridge, & Adolphe, 2010; Kilgour, 2006; Lalor, 2006; Welch, 2010) and overseas (Fraser, 1981; Fraser, Aldridge, & Adolphe, 2010; Lowe, 2004; Tulloch, 2011). Given these findings, the factor structure, internal consistency reliability (Cronbach's alpha coefficient) and ability to differentiate between classes (ANOVA results) were considered sufficient evidence to support the reliability and validity of the TOSRA in this study. Further, these findings suggest that the results of analyses used to answer the subsequent research questions involving these data may be interpreted with confidence.

5.2.1.2 Validity and Reliability of the What is Happening in this Class? Questionnaire

A summary of the key findings for the validity and reliability of the WIHIC questionnaire are listed below:

- Principal axis factor analysis with oblique rotation found that five of the 56 items did not fit the criteria (items 6 and 8 from the Student Cohesiveness scale, 23 and 24 from the Involvement scale and item 36 from the Task Orientation scale). These items were omitted from all further analyses.
- The remaining 51 items all loaded at or above .40 on their own scale and below .40 on all other scales for the data collected during Phases 1 and 2.
- Regarding the WIHIC data collected in Phase 1 –
    - the percentage of variance ranged from 2.84 to 28.55, with a total percentage variance of 59.65%
    - the eigenvalues ranged from 1.42 to 14.27.
- Regarding WIHIC data collected in Phase 2 –
    - the percentage of variance ranged from 3.17 to 32.05, with a total percentage variance of 60.20%
    - the eigenvalues ranged from 1.56 to 16.02.
- The internal consistency reliability (Cronbach's alpha coefficient) for individual WIHIC scales for –
    - data collected during Phase 1 ranged from .79 to .92 with the individual as the unit of analysis and .84 to .93 with the class mean as the unit of analysis

  - data collected during Phase 2 ranged from .79 to .93 with the individual as the unit of analysis and .84 to .93 with the class mean as the unit of analysis.
- The ANOVA results indicated that –
  - for data collected in Phase 1, all seven WIHIC scales were able to differentiate significantly between classrooms
  - for data collected in Phase 2, all WIHIC scales, except the Investigation scale, were able to differentiate significantly between classrooms.

The results provided support for the refined WIHIC questionnaire used in this study. In all cases, the eigenvalues were greater than one, thereby meeting Kaiser's (1960) cut-off. Further, the internal consistency reliability for individual scales was above .50 (for both datasets) on all WIHIC scales, which is considered acceptable based on the criteria outlined by Yusoff (2012) and Schmitt (1996). These findings compare favourably with the results of numerous recent studies using the WIHIC questionnaire conducted worldwide (Dorman, 2003; Ogbuehi & Fraser, 2007), as well as those conducted in Australia (Deieso, 2018; Quinn, 2021; Velayutham & Aldridge, 2013). Most of these studies supported the factorial validity of the WIHIC questionnaire. The results of this study provide strong evidence to support the reliability and validity of the WIHIC questionnaire when used with this study's sample of students in South Australia. Given these findings, the results of subsequent research questions may be interpreted with confidence.

5.2.2 Girls and Secondary School Science

The second research question sought to provide an overview of girl's attitudes towards science classes and their perceptions of the learning environment created in science classrooms in secondary school. The average item means and standard deviations were calculated for each TOSRA (attitude towards science) and WIHIC (learning environment perceptions) scale to determine the results to help understand girls' views. The sample for this analysis involved 130 girls in Phase 2 (secondary school). The results are summarised below:

- The average item means for the different TOSRA scales ranged from 2.61 to 3.75, with students rating their Attitudes to Scientific Inquiry most positively ($\mu = 3.75$, $\sigma = 0.68$) and Career Interest in Science least positively ($\mu = 2.61$, $\sigma = 0.76$).
- Examination of the variation of responses to each TOSRA scale, indicated that –
    - the largest variation in responses was for the Enjoyment of Science attitude scale.
    - three TOSRA scales (Attitudes to Scientific Inquiry, Career Interest in Science and Normality of Scientists) showed outliers (responses fell more than 1.5 times the length of the box from either end of the box)
    - regarding Attitudes Towards Scientific Inquiry and Normality of Scientists, the outliers suggested that views obtained from these scales were considerably less favourable for a minority of girls. For these scales, students' responses fell between 'strongly disagree' and 'disagree'
    - in contrast, regarding one TOSRA scale, Career Interest in Science, the outliers suggested more favourable attitudes for a minority of girls, who responded between 'agree' and 'strongly agree'.
- The average item means for the different WIHIC scales ranged from 3.42 to 4.40, with students rating Student Cohesiveness most positively ($\mu = 4.40$, $\sigma = 0.46$) and Investigation least positively ($\mu = 3.42$, $\sigma = 0.75$).
- Examination of the variation of responses for each WIHIC scale indicated that –
    - the largest variation in responses was for the Investigation learning environment scale
    - except for the Involvement scale, all scales had outliers (responses fell more than 1.5 times the length of the box from either end of the box)
    - regarding Task Orientation, Cooperation and Equity, the outliers suggested a less favourable learning environment for a minority of the girls
    - regarding Teacher support, the outliers suggested a less favourable learning environment for a minority of girls.

The research findings in this study provide an overview of girls' attitudes towards science classes and their perceptions of the learning environment created in science classrooms in secondary school. For these girls, the responses indicated that career interest was low. This finding is similar to those of other studies that have found that the number of young girls choosing to pursue scientific careers continues to decrease (Australian Government, 2017; Kinskey, 2020; Office of the Chief Scientist, 2020). In particular, middle and secondary school students are losing their interest in science-related careers (Potvin & Hasni, 2014).

In reflecting on my experiences as a girl learning science, when I reached middle school I found a renewed passion and excitement for science. In the beginning years of middle school I recall learning about scientific careers and the various pathways that science could take me. When I reached secondary school, this passion was not as strong and the scientific career conversations were not as prominent or promoted within the curriculum. Therefore, as I journeyed through middle school to secondary school my career interest in science lowered.

As mentioned earlier in the thesis, the Australian Government has implemented many initiatives in recent years to support the pursuit of girls in science. These initiatives include: the Girls in STEM Toolkit (Australian Government, 2021a), aimed at encouraging girls to study and pursue careers in STEM; the Advancing Women in STEM Strategy (Australian Government, 2019), aimed at increasing gender equity in STEM education and employment; and the Women in STEM Ambassador program (Australian Government, 2021b), aimed at promoting awareness of STEM careers and at gender-inclusive STEM education for boys and girls. In addition to these initiatives, the National Science Statement (Australian Government, 2017) articulates the need to expand girls' capability in STEM. However, it would appear that even with these initiatives in place, girls continue to display low career interest in the sciences. These findings suggest that there is still a need to promote career pathways and find ways to improve the aspirations of girls to pursue science-related careers. While the subsequent research questions sought to clarify these findings, the results indicate that it could be important for curriculum developers and policymakers to consider improving girls' interest in science as a career (Recommendation 1). One such example might include programs in which female scientists can attend schools to mentor and inspire adolescent girls and raise awareness of girls in science and STEM.

5.2.3 Differences Between Girls in Different Settings

The next two research questions sought to examine the responses of girls in different settings. In this section, first, differences between girls' responses in co-educational and single-sex schools are discussed (Section 5.2.3.1), and then differences between girls' responses between primary and secondary schools are discussed (Section 5.2.3.2). MANOVA and effect sizes were calculated to determine whether attitudes and learning environment perceptions differed among girls in co-educational and single-sex schools and in primary and secondary schools.

5.2.3.1 Differences Between Co-educational and Single-sex Settings: Attitudes and Learning Environment Perceptions

The third research question examined whether differences existed for girls in co-educational and single-sex settings regarding their attitudes towards science and their perceptions of the learning environment. The sample for these analyses involved 130 girls in secondary science classes: 55 were from single-sex settings and 75 were from co-educational settings. The WIHIC and TOSRA scales were the dependent variables, and the school type (co-educational/single-sex) was the independent variable. This section summarises and discusses the results for the TOSRA, followed by the results for the WIHIC questionnaire.

Test of Science Related Attitudes Results

The results for the TOSRA are summarised below:

- The average mean for different TOSRA scales indicated that girls had more positive attitudes in co-educational settings than in single-sex settings.
- Differences between girls in co-educational and single-sex settings were statistically significant ($p < .05$) for four of the five TOSRA scales (namely,

Social Implications of Science, Normality of Scientists, Enjoyment in Science and Career Interest in Science).

- Analyses of the qualitative data indicated that girls (in co-educational settings) felt that having boys in the class made science lessons more enjoyable.

The findings reported above indicate that a co-educational setting promoted more favourable attitudes towards science for girls. While the findings of this study differ from those of some past research (Belfi et al., 2012; Monaco & Gaier, 1992; Sikora, 2014), they support those of other studies (e.g., Halpern, et al., 2011; Koniewski & Hawrot, 2021, Pahlke et al., 2014), which also reported more favourable attitudes for girls in a co-educational setting when compared with a single-sex setting. For example, past studies have reported more favourable career aspirations in science for girls in co-educational settings (e.g., Koniewski & Hawrot, 2021), while other studies have reported that single-sex schools have few advantages for girls (e.g., Pahlke et al., 2014). Despite the mixed results of past studies, the results of the research reported in this thesis highlight that co-educational settings could be advantageous for girls in science classrooms. When considering which school to send their child, these findings could be of significance to parents, particularly parents of girls. These findings demonstrate that a co-educational setting can be more favourable for girls and that their daughter may have more favourable attitudes towards science in a co-education setting.

For teachers of single sex settings, these findings provide evidence to suggest that interaction with boys can have a positive effect on girls' attitudes towards science. Therefore, the results of this study may encourage teachers to find further opportunities for this interaction. Teachers may consider opportunities for offering co-educational science lessons in collaboration with local or partner schools or may consider opportunities for mixed-sex collaboration beyond the science classroom. For teachers in a co-educational setting, it provides insight into the positive influence of boys and may support teachers' actions in regards to flexible grouping to ensure there is ongoing collaboration between the sexes. Although this research has provided insights into why girls in co-education schools found science more interesting, given the inconclusive findings of past research, further studies are recommended to examine why this might be the case (Recommendation 2).

What Is Happening in This Class? (WIHIC) Questionnaire Results

The results for the WIHIC are summarised below:

- The average item means for different WIHIC scales indicated that, for six of the seven scales, the learning environment scores were higher for girls in co-educational schools compared with girls in single-sex schools.
- Differences in scores for girls in co-educational and single-sex settings were statistically significant ($p < .05$) for three of the seven WIHIC scales – Teacher Support, Investigation and Equity – suggesting that girls in co-educational settings had more favourable learning environment perceptions.
- The qualitative information supported the quantitative results, indicating that girls in a single-sex setting demonstrated more confidence than their co-educational class counterparts, particularly in terms of sharing their understandings in class. It also indicated the positive influence of boys in a co-educational setting. The positive influence of boys appeared to be influential in terms of girls' views of their science learning and experience.
- For all the girls interviewed, approximately 31% felt that having boys in the class contributed to more positive perceptions of the learning environment.
- Analysis indicated that girls in both single-sex and co-educational settings felt that having boys in the class made or would make science more fun and interesting. Many of the girls in both settings thought that boys had a positive influence for two reasons. First, they made science more fun during investigations, and second, boys were better at science compared with girls which positively influenced their attitudes towards science.

The findings indicate that co-educational settings provide a more favourable learning environment for girls in science classes. Concerning students' attitudes, the findings of this study differ from those of past studies that reported single-sex settings positively influenced girls' behaviours and abilities in science (Belfi et al., 2012) and their career aspirations and achievement (Koniewski & Hawrot, 2021; Monaco & Gaier, 1992). It is possible that the difference in findings can be attributed to past studies being conducted in different countries or involving different measures. Given the difference in results and the importance of improving student attitudes in science, it is recommended that future research examine further whether single-sex settings are indeed beneficial for girls', particularly in the Australian context (Recommendation 3).

There is little research on girls' perceptions of the learning environment that focuses on girls in these different settings. My findings suggest that girls in co-educational settings have more favourable perceptions of the learning environment and that co-educational settings promote more teacher support, investigation and equity for girls compared with single-sex settings. Although having boys in science classrooms would appear to result in more positive learning environment perceptions, it is concerning that girls reported more confidence challenges in co-educational settings. Given these findings, it is recommended that further studies examine why the presence of boys promotes more positive learning environment perceptions for girls yet hinders confidence for girls (Recommendation 4). To my knowledge, no other studies have examined whether differences exist for girls in single-sex and co-educational settings; therefore, these findings provide important information that helps to fill this research gap.

5.2.3.2 Primary to Secondary School: Learning Environment Perceptions and Attitudes

The fourth research question sought to determine whether girls' perceptions of the learning environment and attitudes differed between primary and secondary school settings. MANOVA and effect sizes were calculated to determine students' views of the primary school experience (Phase 1) when compared, eight months later, with their secondary school experience (Phase 2). For research question 4, the analysis involved a matched sample of 130 girls who responded in Phases 1 and 2. One-way MANOVA was used to determine whether differences were statistically significant. The univariate ANOVA results were interpreted for both the TOSRA and WIHIC data. The results are summarised and discussed separately for the TOSRA and WIHIC data.

Test of Science Related Attitudes Results

- Regarding two of the five TOSRA scales (Career Interest in Science and Normality of Scientists), students reported more favourable attitudes towards science in Phase 2 (secondary school) than at Phase 1 (primary school). The direction of difference was positive.
- Regarding three of the five TOSRA scales (Attitudes to Scientific Inquiry, Enjoyment of Science and Social Implications of Science), students' attitudes were more positive in Phase 1 (primary school) than in Phase 2 (secondary school). The direction of difference was negative.
- The differences in scores were statistically significant ($p < .05$) for three of the five TOSRA scales, as follows –
  - For one scale, Normality of Scientists, girls scored higher in Phase 2 than in Phase 1, suggesting they viewed scientists as more normal after attending secondary school for eight months.
  - For the Attitudes to Scientific Inquiry and Enjoyment of Science Lessons scales, girls' scores dropped at Phase 2 (secondary school), suggesting that their attitudes were less positive after attending secondary school for eight months.
- Regarding the analysis of the qualitative information –
  - girls' confirmed that becoming a scientist was viewed more favourably by them in secondary school compared with primary school.
  - girls' images of scientists when in primary school were very different from those in secondary school; y viewed scientists to be more 'normal' when they were attending secondary school
  - contrary to the quantitative data, girls held more favourable attitudes towards scientific inquiry in secondary school compared with primary school.

What Is Happening in This Class? Questionnaire Results

- Results indicated that for all seven WIHIC scales, girls scored higher in Phase 2 (secondary school) compared with Phase 1.

- The scores were statistically significant ($p < 0.05$) for only one WIHIC scale, Equity. For this scale, girls viewed classrooms as less equitable in Phase 1 (primary school) than in Phase 2 (secondary school).
- Analysis of the qualitative information indicated that –
    - in terms of Teacher Support, girls expressed more positive views of their secondary school science teachers compared with their primary school science teachers
    - in terms of Investigation, girls expressed more positive views in secondary school because investigations carried out in primary school were primarily held in the classroom, whereas, in secondary school, students had access to laboratories.

Interestingly, the results showing more positive attitudes and perceptions in secondary school differ from those of most past studies (Deieso, 2018; Jindal-Snape & Cantali, 2019; Moje, 2008). Past research reported that the transition from primary to secondary school was not a positive one and that, relative to primary school, secondary school students had less-positive attitudes and classroom environment perceptions (Hine, 2001; Deieso, 2018; Speering, 1996). Further, past research reports less favourable interest in science in secondary school compared with primary school (Barmby et al., 2008; Kahle & Lakes, 1983; Potvin & Hasni, 2014). Conversely, the results of this study indicate that girls in secondary school experienced their science classrooms more favourably than in primary school. These differences in results could be attributed to the all-girls sample used in this study. Given that past research has highlighted the importance of engagement in STEM at an early age (Rosicka, 2016), further research is recommended to investigate whether the trend is unique for girls (Recommendation 5).

Although not statistically significant, regarding girls' perceptions of the learning environment, the qualitative data indicate that hands-on investigation and access to scientific laboratories were more prevalent in secondary school. Involvement in investigations related to how girls learned in their science classroom. Many of the girls (approximately 79%) indicated that there were more opportunities for hands-on investigation in the secondary science classroom compared with the primary science classroom. Access to scientific laboratories was related to the physical surroundings in the science classroom. In this case, the girls attributed the increase in hands-on investigations to having more access to scientific laboratories in the secondary science classroom compared with the generic classroom in primary school. The findings indicate that access to scientific laboratories in secondary schools influenced students' attitudes towards their science classrooms. These findings suggest that incorporating a scientific laboratory environment in the primary school setting could benefit girls' attitudes towards science at a younger age, thereby promoting more engagement and aspiration for science in the later years. Therefore, it is recommended that further research examine the efficacy of including laboratories at the primary school level (Recommendation 6).

In reflecting on my experiences as a girl learning science, I recall having a more favourable experience of science in secondary school when compared to primary school. This was mostly due to the exposure to a broader range of scientific topics and access to scientific laboratories. I recall feeling important and felt that learning science was important at the time.

Further, although not statistically significant, girls' perceptions of teacher support were more positive in secondary school compared with primary school. This finding supports past research (Eccles, 2007; Lalor, 2006; Peer, 2011), which showed that girls had more positive perceptions of Teacher Support. Although the qualitative results did not report a statistically significant difference in Teacher Support between primary school and secondary school experiences, the qualitative information indicated that the teachers' passion and knowledge were necessary. For many of the students (approximately 74%), the teachers' approach to science teaching was essential. Analysis indicated that if a teacher was passionate about teaching science, students were more likely to hold more positive perceptions about their science lessons. The results also indicated that these students felt their secondary school science teachers were more passionate about science than were their primary school teachers.

Since teacher's knowledge of and passion for science influenced students' attitudes towards science, it is recommended that further professional development be provided for in-service primary school teachers. It is recommended that professional learning provide teachers with the knowledge to help students to learn deepened scientific content and to engage in more opportunities for inquiry (Recommendation 7). The findings also support the need for a compulsory science education component for pre-service teachers (Recommendation 8) and that primary schools be supported to engage specialist science teachers in the primary years (Recommendation 9).

5.2.4 Sex Differences

This section summarises and discusses the findings for the differences between boys' and girls' attitudes to science and learning environment perceptions at the secondary school level. These differences were examined only for those students enrolled in co-educational schools. The sample involved 149 secondary science students, of whom 74 were boys and 75 were girls. Given that boys and girls are not found in equal numbers in every class, the within-class gender means provided a matched pair of means – one within-class mean for girls and one within-class mean for boys. For this analysis, student sex was the independent variable. A summary and discussion of the results are provided separately for the TOSRA and WIHIC data.

Test of Science Related Attitude Results

- None of the TOSRA scales showed a statistical significance in the differences in attitude scores between boys and girls.
- The qualitative data indicated that –
    - there were some sex stereotypes related to the social implications of science and career interest in science
    - many girls (and some boys) expressed that they felt that boys were better at science than girls and that they (boys) were more likely to undertake a career in science.

The results for the quantitative data analyses suggest there were no statistically significant differences in attitudes between boys and girls. This finding differs from findings of past research, which indicated that boys have a more favourable career interest in science compared with girls (e.g., Holmes et al., 2017).

Although there were no statistically significant differences for the TOSRA scales, the qualitative information told a different story, indicating sex stereotypes in science classrooms related to social implications of science and career interest in science. The qualitative results support those of other studies (Gugliotta, 2010; Hill et al., 2010; Ryan, 2016), which have found that gender stereotypes have a significant influence in classrooms. This finding is important given that gender stereotypes can have a significant influence on STEM career aspirations (Makarova et al., 2019) and that girls, compared with boys, experience more negative stereotypes about their abilities in science (Hand et al., 2017). At the end of primary school, the students portrayed scientists using an image of a mad male scientist. This image has been reported across other studies (Barman, 1997; Chambers, 1983; Narayan & Peker, 2009; Todd & Zvoch, 2019) that documented similar findings.

The findings reported in this thesis suggest that teachers need to be aware of the gender stereotypes in science and how this affects perceptions and attitudes towards science, particularly for girls. Therefore, it is recommended that teachers undertake targeted professional learning that highlights how gender stereotypes can affect students, so that they can take action to avoid this (Recommendation 10). Further, it is recommended that teachers create learning environments in which girls feel safe and confident and promote the belief that girls can pursue a career in science. Further information detailing the relationships between the learning environment and career aspirations is detailed in Section 5.2.5.1. This promotion could also include opportunities to engage with positive female mentors in the STEM industry (Recommendation 11). Given these findings, coupled with the lack of research related to how teachers can promote the success of girls in STEM, it is recommended that further studies examine how this might be done effectively (e.g., the effectiveness of providing positive female role models in secondary school science settings) (Recommendation 12).

What Is Happening in This Class? Questionnaire Results

- The average item means indicated that the scores were higher for girls than for boys for all seven WIHIC scales.

- Differences in scores for boys and girls were statistically significant ($p < .05$) for five of the seven WIHIC scales: Student Cohesiveness, Teacher Support, Equity, Task Orientation and Cooperation.
- Analysis of the qualitative data indicated that –
    - Student Cohesiveness was an important aspect of the learning environment for many girls, but not mentioned by any boys
    - the majority of girls expressed that having friendships in the classroom provided a support network within the class
    - both boys and girls enjoyed the subject matter taught in their secondary science classes, expressing that the breadth of subject material and various ways of learning made science more interesting
    - many girls, compared with boys, expressed that it was the teacher who enhanced their interest in and enjoyment of science
    - girls expressed concern about sharing their ideas in class because girls felt, generally, that boys were better at science than girls.

These results, which found that girls had more positive perceptions of the classroom learning environment than did boys, support numerous studies with similar findings (Eccles, 2007; Fraser & Raaflaub, 2013; Huang & Fraser, 2009; Lim, 1995; Peer, 2011). This study highlighted that positive relationships are important, and in the qualitative findings, the girls indicated that these relationships helped improve cohesiveness.

In reflecting on my experience as a girl learning science, I recall the impact of positive relationships in my science classroom. For example, I remember feeling a sense of pride and increased engagement when I had a supportive and encouraging teacher. This was the same case through middle and secondary school and into university. I recall the sense of pride when I got a hypothesis correct or wrote a laboratory report to a high standard. The reason I remember this was the way the teacher encouraged me to learn, test and trial more and provided positive feedback along the way. Further to this, I remember enjoying science more when I had friends in my class who I could partner with during experimentation and who could support me if I had questions or needed guidance. I also vividly recall the jump from primary to middle school in regards to science content. As soon as I reached middle school, there was so much more breadth to the science lesson and this was where my eyes were opened to the various fields of science and their application in society. I recall having a sense of excitement and interest when being exposed to this increased breadth of scientific content.

Regarding the qualitative data, girls often discussed aspects of the learning environment, such as the support network they experienced in their class through friendships, which none of the boys discussed. It is therefore recommended that educators prioritise the building and maintaining of relationships within science classes (Recommendation 13). Doing so would promote positive learning environment perceptions, particularly for girls. Creating a culture of trust and a sense of belonging is an important aspect of teaching. Given the qualitative data results demonstrating that girls expressed concern about sharing their ideas in class, it is recommended that teachers develop and nurture a supportive and trusting science classroom culture (Recommendation 14).

5.2.5 Relationships Between Learning Environment and Attitudes Towards Science and Achievement

The sixth research question examined whether relationships exist between girls' perceptions of their science classroom environment and their attitudes towards science. The sample for these analyses involved 130 girls in secondary science classes. Simple correlation analysis (r) and multiple regression (R) analysis were used to examine the relationships. This section is divided into two parts. First, a summary and discussion of the key findings of the environment–attitude relationships are reported (Section 5.2.5.1), then a summary and discussion of the environment–achievement relationship (Section 5.2.5.2) are provided.

5.2.5.1 Environment–Attitude Relationships

This section discusses the environment–attitude relationships, covering simple correlation analysis, multiple correlation analysis and standardised regression weights for each TOSRA scale. As summarised below, the results indicate statistically significant relationships between the learning environment and four of the five TOSRA scales:

- Social Implications
  - The results of the simple correlation analysis indicate that four of the seven WIHIC scales were positively statistically significantly ($p < .01$) related: Teacher Support, Involvement, Investigation and Task Orientation.
  - The multiple correlation (R) was .50, positive and statistically significant ($p < .01$).
  - The standardised regression weights (β) were positive and statistically significant ($p < .01$) for two WIHIC scales: Investigation and Task Orientation.
- Normality of Scientists
  - Simple correlation analysis indicates that three WIHIC scales were positively and statistically significantly ($p < 0.1$) related to Normality of Scientists: Involvement, Investigation I Task Orientation.
  - The multiple correlation (R) was .38, positive and statistically significant ($p < .01$).
  - The standardised regression weights (β) were positive and statistically significant ($p < .05$) for two WIHIC scales: Social Cohesiveness and Investigation.
- Enjoyment of Science
  - Simple correlation analysis indicates that six WIHIC scales were positively statistically significantly ($p < .01$) related: Teacher Support, Involvement, Investigation, Task Orientation, Collaboration and Equity.
  - The multiple correlation (R) was .60 and was positive and statistically significant ($p < .01$).
  - Two WIHIC scales were significantly ($p < .01$), positively and independently related: Investigation and Task Orientation.
- Career Interest
  - Simple correlation analysis indicated that five of the seven WIHIC scales were positively statistically significantly ($p < .01$) related: Teacher Support, Involvement, Investigation, TI Orientation and Equity.

- The multiple correlation (R) for the learning environment scales was .44 and was positive and statistically significant ($p < .01$).
- One WIHIC scale was significantly ($p < .01$), positively and independently related: Investigation.

To summarise, these results suggest that, for girls, a positive relationship exists between the classroom learning environment and their attitudes towards science. The results show that Social Implications, Normality of Scientists, Enjoyment of Science and Career Interest all improve for girls in science through support from the teacher, increased involvement, increased opportunities for investigation and opportunities for girls to engage with the tasks presented within the science class.

In reflecting on my experience as a girl learning science, this was also the case. When I felt supported by the teacher and had increased opportunities for hands-on investigation and engagement with tasks, my attitude towards science was more positive. I recall having a number of science lessons during the week and not all of them were in the science laboratory. I remember the feeling of excitement when it was the scheduled day to be in the science laboratory. This excitement was due to the fact that if we were in the laboratory, it would likely mean that we would be doing an experiment and I loved opportunities for hypothesising, investigating and experimenting. I have always been more of a visual/ hands-on learner so this experience in the laboratory always increased my engagement and attitudes towards science.

These are important findings for science teachers as they provide clear suggestions as to how they might improve student attitudes in the science classroom. Further to this, these findings are also important for professional development providers, again, giving them clear suggestions on how to target improvement in science. For example, they may provide targeted professional learning around investigation and involvement in the science classroom or targeted professional learning about how teachers can provide different levels of support to their students in the science classroom.

The results of this study support the findings of other studies showing a positive relationship between a more favourable classroom learning environment and a range of outcomes (Adamski et al., 2013; Lee, 2010; Madu, 2010; Rucinski et al., 2018), including attitudes towards science. Given the positive relationships between a favourable learning environment and positive attitudes towards science, it is essential that teachers continually gather feedback from students related to their classroom learning environment to provide and support a positive environment. Therefore, it is recommended that teachers continually assess the factors that influence students' perceptions of the learning environment through the use of a short ongoing quantitative survey as students journey through their secondary years of schooling (Recommendation 15).

5.2.5.2 Environment–Achievement Relationships

This section summarises and discusses in the points below the results of the simple correlation and multiple regression analysis used to determine whether relationships existed between girls' perceptions of their science classroom environment and their achievement in science:

- All seven environment scales (Social Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Collaboration, and Equity) were statistically significantly and positively correlated ($p < .01$) with science achievement.
- These statistically significant correlations were positive, suggesting a strong association between a favourable classroom learning environment and girls' achievement in science.
- The multiple correlation (R) was .44 and was positive and statistically significant ($p < .01$).
- No learning environment scales were significantly, positively and independently related to Science Achievement.
- To summarise, this data suggests that, for the most part, a positive relationship exists between a favourable classroom learning environment and students' science achievement.

These results support those of past studies (e.g., Spearman & Watt, 2013) that have demonstrated that learning environment perceptions influence achievement for girls.

Moreover, my findings support previous studies (MacDonald et al., 2020) that report that using effective teaching strategies and abstractly representing content to make cross-curricular links can be beneficial. These findings are significant to science teachers as they demonstrate just how influential the science classroom learning environment can be. If girls do not learn in a positive and engaging learning environment where they can flourish, this directly affects their achievement in science. Factors such as social cohesiveness, teacher support, opportunities for involvement and investigation, task orientation, opportunities for collaboration, and equity all influence science achievement for girls. Therefore, it is recommended that teachers, in both primary and secondary settings, provide an engaging and rich science curriculum and pedagogical approach focusing on all of the learning environment scales to ensure positive perceptions and attitudes towards science (Recommendation 16).

5.3 Limitations

The study presented in this thesis, like all studies, was not free of limitations. This section outlines the limitations of the paradigm, methods and sample used in the study, as well as those associated with the researcher.

Since this study was undertaken using an interpretivist paradigm, this brings with it limitations. Although using an interpretivist paradigm allowed for an in-depth examination exploring students' attitudes and perceptions, it also limited the potential generalisability of the study beyond the specific context of Australia and the objectivity of the research. The nature of this research was to give voice to students concerning their experiences and perceptions in the context of secondary school in South Australia. Therefore, it is recommended that future researchers consider students' perceptions and attitudes towards science from a range of perspectives, including using post-positive and critical paradigms and also through the experiences of other stakeholders beyond just the students themselves (Recommendation 17).

Even though every effort was made to ensure that a range of schools was included, it is acknowledged that the sample size was restricted because it was limited to students only in Year 8. Further to this, a limitation was the number of boys involved in the study. Although the study focused on girls, it was important to gain boys' perspectives to measure sex differences. A further limitation was the location of schools. This restriction means that generalising to other regions within Australia will need to be undertaken with caution. It is recommended that future research into student attitudes and perceptions of the classroom learning environment, particularly in relation to girls, should consider the perspectives of further students not included in the sample space for my study (Recommendation 18).

Regarding the sample size and selection, difficulties were encountered when engaging secondary schools to collect the data. The collection of the quantitative data was undertaken in collaboration with the science teachers. This commitment was too much for some schools since many teachers were time-poor and had competing priorities. As part of the data collection, teachers were asked to collate the consent forms and mail the hard copies of the surveys, which was time-consuming. Several students at the schools did not return a consent form and therefore could not be involved in the study. Hence, it is recommended that the surveys be administered electronically in future studies. Doing so would alleviate some of the commitments and time pressures for the teachers and render the process more efficient, thereby allowing for a higher participation and response rate (Recommendation 19).

The duration of the data collection could have spanned a more extended period to track in further detail how students' perceptions of the science learning environment and their attitudes towards science change throughout their secondary schooling. Therefore, a limitation of this study was the reliance on retrospective views (rather than using Year 7 and 8 data). Further, data could be collected after students' secondary years to measure how many girls undertake or aspire to undertake a career in science, technology, engineering or mathematics. Therefore, to provide richer insights into these trends, it is recommended that future studies provide longitudinal evidence gathering (Recommendation 20).

The negatively worded items presented in the TOSRA could have presented a limitation. This resulted in a large number of items being omitted from analyses. It would appear that the use of negative items may have confused many students. Therefore, it is recommended that future researchers who use the TOSRA as an instrument consider presenting it so that the response format is consistent, for example, all positive or all negative (Recommendation 21).

Lastly, my emerging skills as a researcher may have limited the quality and accuracy of the study, particularly in the analysis of the qualitative data. Since I was the person who analysed the data, I constructed meaning around the experiences, attitudes and perceptions held by students. Therefore, the thematic analysis might have been subjective because it relied on the judgement of the researcher.

5.4 Summary of Recommendations

This section provides a summary of the recommendations made above.

Recommendation 1	Curriculum developers and policymakers consider programs in which female scientists can attend schools to mentor and inspire adolescent girls and raise awareness concerning girls in science and STEM
Recommendation 2	Further research examine why co-educational settings are more advantageous for girls in science classrooms.
Recommendation 3	Future research examine further whether single-sex settings are indeed beneficial for girls, particularly in the Australian context.
Recommendation 4	Further research examine why the presence of boys promotes more positive learning environment perceptions for girls yet hinders confidence for girls.
Recommendation 5	Further research investigate whether the trend of more positive attitudes and perceptions towards science in secondary school compared to primary school is unique for girls, given that past research has highlighted the

importance of engagement in STEM at an early age (Rosicka, 2016).

Recommendation 6	Further research examine the efficacy of including laboratories at the primary school level.
Recommendation 7	Professional development for primary teachers be provided to enable students to learn deepened scientific content and engage in more opportunities for inquiry.
Recommendation 8	Specialist science courses be incorporated into undergraduate teaching degrees.
Recommendation 9	Specialist science teachers be engaged at school in the primary years.
Recommendation 10	Teachers undertake targeted professional learning, which highlights how gender stereotypes can affect students and how to avoid this.
Recommendation 11	Teachers promote a learning environment that enables girls to feel safe and confident and encourages their belief that they can pursue a career in science. This promotion could also include opportunities to engage with positive female mentors in the STEM industry.
Recommendation 12	Further research examine how providing positive female role models in secondary school science settings might be done effectively.
Recommendation 13	Educators prioritise the building and maintaining of relationships within science classes.

Recommendation 14 Teachers develop and nurture a supportive and trusting science classroom culture.

Recommendation 15 Teachers continually assess the factors that influence students' perceptions of the learning environment through the use of a short ongoing quantitative survey as students journey through their secondary years of schooling.

Recommendation 16 Teachers, in both primary and secondary settings, provide an engaging and rich science curriculum and pedagogical approach to ensure positive attitudes and perceptions towards science.

Recommendation 17 Future researchers consider students' perceptions and attitudes towards science from a range of perspectives, including using post-positive and critical paradigms and through other stakeholders' experiences beyond just the students themselves.

Recommendation 18 Future research into student attitudes and perceptions of the classroom learning environment, particularly regarding girls, consider the perspectives of further students not included in the sample space for this study.

Recommendation 19 The surveys be administered electronically in future studies. Doing so would alleviate some of the commitments and time pressures for the teachers and make the process more efficient, allowing for a higher participation and response rate.

Recommendation 20 Future research provide longitudinal evidence gathering.

Recommendation 21 Researchers who use the TOSRA as an instrument consider presenting in such a way that the response format is consistent, for example, all positive or all negative.

5.5 Significance of the Study

Despite its limitations, the results of this study are valuable for several reasons. This section outlines the significance of the study's findings and their implications.

The present study makes a significant contribution to the limited literature related to girls and STEM in Australia. This research adds to the body of past global research exploring attitudes and learning environment perceptions regarding girls in science classrooms. More specifically, its findings are based on different science classroom settings. To my knowledge, no other studies have examined whether differences exist for girls in single-sex and co-educational settings; hence, these findings provide important information that helps to fill this research gap. These results therefore have implications for the Australian Government in promoting their 'Advancing Women in STEM strategy', and they provide valuable insights into the factors within the education system that contribute to girls' attitudes and perceptions towards science. An education system that actively supports and encourages girls in STEM, from early education to tertiary level, will help build a workforce of Australian women empowered to make scientifically informed decisions and take advantage of the opportunities of the future jobs (Australian Government, 2019).

This study extends past research, offering new insights into reasons for low rates of engagement with science and STEM for girls. The implications of these findings offer educators and curriculum developers insight into how they can improve girls' experiences in science and encourage aspirations for girls to pursue science. The implications of these findings offer educators insight into what areas of the learning environment they could target to ensure the most significant effect on girls' attitudes towards and engagement in science and their career aspirations.

There has been limited research into how different science classroom settings influence girls' attitudes and perceptions towards science. Therefore, the findings of this study could be of significance to educators. These findings could maximise girls' engagement in science, attitudes towards science, learning environment perceptions and career aspirations in science and STEM. Specifically, educators could consider focusing on their pedagogical approach to teaching science to girls, their development of classroom structures, and student groupings and learning environment features.

The findings offer further insight into gender stereotypes within the fields of science. With rising statistics showing a global STEM gap with an under-representation of girls and women showing interest in or pursuing a career in science, technology, engineering or mathematics, the results of this study provide a timely insight into the factors that contribute to these stereotypes. Numerous factors perpetuate this gender STEM gap, including gender stereotypes, male-dominated cultures, few female role models and a confidence gap (Hill et al., 2010). The results provide insight into gender stereotypes and how positive role modelling is critical for girls' perceptions of science. The findings in this study also highlight the need for teachers to be responsible for presenting science as equally appropriate for girls and boys and to break down the gender stereotypes associated with science education. Therefore, this study holds significance for policymakers, curriculum developers, professional learning providers, teachers and school leaders in promoting STEM, particularly for girls.

This study provides curriculum developers and policymakers with information about the critical importance of STEM education throughout the primary years and beyond, so that every student is exposed to an engaging learning environment with positive role models and that STEM experiences are connected to girls' lives. It highlights to policymakers, school leaders and teachers how classroom environments in both the primary and secondary years influence attitudes towards science. Such information has the potential to inform transition programs and career aspirations in science, particularly for girls.

The study holds significance for the STEM workforce, providing insights into the importance of the career sector engaging and supporting girls in science when they reach high school to foster and inspire career aspirations in STEM fields.

Overall, the results offer important insights to school and system leaders regarding learning environment design and pedagogical practices in science. The study highlights the importance of investigation and the positive impact of having access to scientific laboratories at school. This has implications for school and system leaders in relation to incorporating these provisions. Further, the study highlights to universities, school and system leaders the importance of targeted professional learning for teachers – both primary and secondary – concerning the importance of specialist science and the incorporation of STEM in the curriculum. These findings support the inclusion of specialist science courses in undergraduate teaching degrees and targeted professional learning for practising teachers.

5.6 Concluding Remarks

This research is important because it identifies factors within various settings that affect girls' attitudes towards science, learning environment perceptions, engagement with science and future career aspirations. Critically, this research contributes to identifying factors within the classroom learning environment in the primary setting that could be improved to enhance investigation and inquiry in the early years and promote engagement with STEM subjects and careers in secondary school and beyond. Lastly, the results of this study highlight the need to continue offering and promoting science and STEM in a gender-balanced way, removing gender stereotypes that may influence future career aspirations and self-belief.

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Appendix 1

PERMISSION TO USE TABLE 2.1

From: Barry Fraser

To: Dunlop, Alice (CESA)

Subject: RE: Permission to use table in my thesis

Date: Sunday, 29 September 2019 3:33:43PM

Attachments: image001.png

Alice

Fine, it is ok to include this table, but you should add a footnote to the table indicating that it was reproduced or adapted from Fraser (2012).

Barry

From: Dunlop, Alice (CESA) [mailto:Alice.Dunlop@cesa.catholic.edu.au]

Sent: Sunday, 29 September 2019 1:01 PM

To: Barry Fraser

Subject: Permission to use table in my thesis

Dear Barry,

I am writing to seek permission to use Table 79.1 from your paper Classroom learning environments: Retrospect, context and prospect. See image below

Table 79.1 Overview of scales contained in some classroom environment instruments (LEI, CES, ICEQ, CUCEI, MCI, QTI, SLEI, CLES, WIHIC, TROFLEI and COLES)

			Scales classified according to Moos's scheme		
Instrument	Level	Items per scale	Relationship dimensions	Personal development dimensions	System maintenance and change dimensions
Learning Environment Inventory (LEI)	Secondary	7	Cohesiveness Friction Favouritism Cliqueness Satisfaction Apathy	Speed Difficulty Competitiveness	Diversity Formality Material environment Goal Direction Disorganisation Democracy
Classroom Environment Scale (CES)	Secondary	10	Involvement Affiliation Teacher support	Task orientation Competition	Order and organisation Rule clarity Teacher control Innovation
Individualised Classroom Environment Questionnaire (ICEQ)	Secondary	10	Personalisation Participation	Independence Investigation	Differentiation
College and University Classroom Environment Inventory (CUCEI)	Higher Education	7	Personalisation Involvement Student cohesiveness Satisfaction	Task orientation	Innovation Individualisation
My Class Inventory (MCI)	Elementary	6–9	Cohesiveness Friction Satisfaction	Difficulty Competitiveness	

Kind regards, Alice

Appendix 2

PERMISSION TO USE TABLE 3.4

From: Barry Fraser

To: Dunlop, Alice (CESA)

Subject: RE: Permission to use table in my thesis

Date: Tuesday, 14 January 2020 2:11:21 PM

Attachments: image001.png

Alice

You are welcome to use this

table. Good luck

Dr Barry J Fraser

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From: Dunlop, Alice (CESA) [mailto:Alice.Dunlop@cesa.catholic.edu.au]

Sent: Tuesday, 14 January 2020 10:28 AM

To: Barry Fraser

Cc: Jill Aldridge

Subject: Permission to use table in my thesis

Dear Barry,

I am writing to seek permission to use Table 1 from Fraser, B.J. (1981). *Test of Science-Related Attitudes* (TOSRA). Melbourne: Australian Council for Educational Research. I will add a footnote to the table indicating that it was adapted from Fraser (1981).

See image below from your paper.

Table 1 Name and Classification of Each Scale in TOSRA

Scale name		Klopfer (1971) classification
Social Implications of Science (S) Normality of Scientists (N)	H.1:	Manifestation of favourable attitudes towards science and scientists
Attitude to Scientific Inquiry (I)	H.2:	Acceptance of scientific inquiry as a way of thought
Adoption of Scientific Attitudes (A)	H.3:	Adoption of 'scientific attitudes'
Enjoyment of Science Lessons (E)	H.4:	Enjoyment of science learning experiences
Leisure Interest in Science (L)	H.5:	Development of interest in science and science-related activities
Career Interest in Science (C)	H.6:	Development of interest in pursuing a career in science

In my thesis, I have adapted it to look like this:

Scale	Klopfer (1971) Classification	Sample Item
Social Implications of Science	Manifestation of favorable attitudes towards science and scientist	Money spent on science is well worth spending. (+)
Normality of Scientists	Acceptance of scientific inquiry as a way of thought	Scientists usually like to go to their laboratories when the have a day off. (-)
Attitude to Scientific Inquiry	Acceptance of scientific attitudes way of thought	I would prefer to find out why something happens by doing an experiment than by being told. (+)
Adoption of Scientific Attitudes	Adoption of 'scientific attitudes'	I am curious about the world in which we live. (+)
Enjoyment of Science Lessons	Enjoyment of science learning experience	I dislike science lessons. (-)
Leisure Interest in Science	Development of interest in science and science-related activities	I would like to belong to a science club. (+)
Career Interest in Science	Development of interest in pursuing a career in science	I would dislike being a scientist after I leave school. (-)

*Adopted from Fraser (1981). Items designated (+) are scored 1, 2, 3, 4, 5, respectively, for the responses strongly disagree, disagree, not sure, agree and strongly agree. Items designated (-) are scored in the reverse manner.

Kind regards, Alice

Appendix 3

TOSRA SURVEY

TOSRA

TEST OF SCIENCE-RELATED ATTITUDES

Barry J. Fraser

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 Item

0 It would be interesting to learn about boats.

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

0 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.

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Page 2

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.

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

17 I would prefer to do experiments 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.

Page 3

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 to 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.

41 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.

Page 4

50 This country is spending too much money on science.

51 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 In science experiments, I report unexpected results as well as expected ones.

61 I look forward to science lessons.

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 more 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.

Test of Science-Related Attitudes

Answer Sheet

Name ______________________________

School ______________________ Year/Class ______________

Page 2						Page 3						Page 4					
	STRONGLY AGREE	AGREE	NOT SURE	DISAGREE	STRONGLY DISAGREE		STRONGLY AGREE	AGREE	NOT SURE	DISAGREE	STRONGLY DISAGREE		STRONGLY AGREE	AGREE	NOT SURE	DISAGREE	STRONGLY DISAGREE
1	SA	A	N	D	SD	29	SA	A	N	D	SD	50	SA	A	N	D	SD
2	SA	A	N	D	SD	30	SA	A	N	D	SD	51	SA	A	N	D	SD
3	SA	A	N	D	SD	31	SA	A	N	D	SD	52	SA	A	N	D	SD
4	SA	A	N	D	SD	32	SA	A	N	D	SD	53	SA	A	N	D	SD
5	SA	A	N	D	SD	33	SA	A	N	D	SD	54	SA	A	N	D	SD
6	SA	A	N	D	SD	34	SA	A	N	D	SD	55	SA	A	N	D	SD
7	SA	A	N	D	SD	35	SA	A	N	D	SD	56	SA	A	N	D	SD
8	SA	A	N	D	SD	36	SA	A	N	D	SD	57	SA	A	N	D	SD
9	SA	A	N	D	SD	37	SA	A	N	D	SD	58	SA	A	N	D	SD
10	SA	A	N	D	SD	38	SA	A	N	D	SD	59	SA	A	N	D	SD
11	SA	A	N	D	SD	39	SA	A	N	D	SD	60	SA	A	N	D	SD
12	SA	A	N	D	SD	40	SA	A	N	D	SD	61	SA	A	N	D	SD
13	SA	A	N	D	SD	41	SA	A	N	D	SD	62	SA	A	N	D	SD
14	SA	A	N	D	SD	42	SA	A	N	D	SD	63	SA	A	N	D	SD
15	SA	A	N	D	SD	43	SA	A	N	D	SD	64	SA	A	N	D	SD
16	SA	A	N	D	SD	44	SA	A	N	D	SD	65	SA	A	N	D	SD
17	SA	A	N	D	SD	45	SA	A	N	D	SD	66	SA	A	N	D	SD
18	SA	A	N	D	SD	46	SA	A	N	D	SD	67	SA	A	N	D	SD
19	SA	A	N	D	SD	47	SA	A	N	D	SD	68	SA	A	N	D	SD
20	SA	A	N	D	SD	48	SA	A	N	D	SD	69	SA	A	N	D	SD
21	SA	A	N	D	SD	49	SA	A	N	D	SD	70	SA	A	N	D	SD
22	SA	A	N	D	SD												
23	SA	A	N	D	SD												
24	SA	A	N	D	SD												
25	SA	A	N	D	SD												
26	SA	A	N	D	SD												
27	SA	A	N	D	SD												
28	SA	A	N	D	SD												

For Teacher Use Only

S ___ N ___ I ___ A ___ E ___ L ___ C ___

Appendix 4

WHAT IS HAPPENING IN THIS CLASS SURVEY

What is Happening in this Class?

Directions for Students

This survey contains statements about practices which could take place in this class. You will be asked how often each practice takes place. There are no 'right' or 'wrong' answers. Your opinion is what is wanted. Think about how well each statement describes what this class is like for you.

Draw a circle around:

-2	if the practice takes place	**Almost Never**
-1	if the practice takes place	**Seldom**
0	if the practice takes place	**Sometimes**
1	if the practice takes place	**Often**
2	if the practice takes place	**Almost Always**

STUDENT COHESIVENESS	**Almost Never**	**Seldom**	**Some-times**	**Often**	**Almost Always**
1. I make friendships among students in this class.	-2	-1	0	1	2
2. I know other students in this class.	-2	-1	0	1	2
3. I am friendly to members of this class.	-2	-1	0	1	2
4. Members of the class are my friends.	-2	-1	0	1	2
5. I work well with other class members.	-2	-1	0	1	2
6. I help other class members who are having trouble with their work.	-2	-1	0	1	2
7. Students in this class like me.	-2	-1	0	1	2
8. In this class, I get help from other students.	-2	-1	0	1	2
TEACHER SUPPORT	**Almost Never**	**Seldom**	**Some-times**	**Often**	**Almost Always**
9. The teacher takes a personal interest in me.	-2	-1	0	1	2
10. The teacher goes out of his/her way to help me.	-2	-1	0	1	2
11. The teacher considers my feelings.	-2	-1	0	1	2
12. The teacher helps me when I have trouble with the work.	-2	-1	0	1	2
13. The teacher talks with me.	-2	-1	0	1	2
14. The teacher is interested in my problems.	-2	-1	0	1	2
15. The teacher checks in with me.	-2	-1	0	1	2
16. The teacher's questions help me to understand.	-2	-1	0	1	2

INVOLVEMENT		Almost Never	Seldom	Some-times	Often	Almost Always
17.	I discuss ideas in class.	-2	-1	0	1	2
18.	I give my opinions during class discussions.	-2	-1	0	1	2
19.	The teacher asks me questions.	-2	-1	0	1	2
20.	My ideas and suggestions are used during classroom discussions.	-2	-1	0	1	2
21.	I ask the teacher questions.	-2	-1	0	1	2
22.	I explain my ideas to other students.	-2	-1	0	1	2
23.	Students discuss with me how to go about solving problems.	-2	-1	0	1	2
24.	I am asked to explain how I solve problems.	-2	-1	0	1	2

INVESTIGATION		Almost Never	Seldom	Some-times	Often	Almost Always
25.	I carry out investigations to test my ideas.	-2	-1	0	1	2
26.	I am asked to think about the evidence for statements.	-2	-1	0	1	2
27.	I carry out investigations to answer questions coming from discussions.	-2	-1	0	1	2
28.	I explain the meaning of statements, diagrams and graphs.	-2	-1	0	1	2
29.	I carry out investigations to answer questions which puzzle me.	-2	-1	0	1	2
30.	I carry out investigations to answer the teacher's questions.	-2	-1	0	1	2
31.	I find out answers to questions by doing investigations.	-2	-1	0	1	2
32.	I solve problems by using information obtained from my own investigations.	-2	-1	0	1	2

TASK ORIENTATION		Almost Never	Seldom	Some-times	Often	Almost Always
33.	Getting a certain amount of work done is important to me.	-2	-1	0	1	2
34.	I do as much as I set out to do.	-2	-1	0	1	2
35.	I know the goals for this class.	-2	-1	0	1	2
36.	I am ready to start this class according to the schedule.	-2	-1	0	1	2
37.	I know what I am trying to accomplish in this class.	-2	-1	0	1	2
38.	I pay attention during this class.	-2	-1	0	1	2
39.	I try to understand the work in this class.	-2	-1	0	1	2
40.	I know how much work I have to do.	-2	-1	0	1	2

COOPERATION	Almost Never	Seldom	Some-times	Ofte n	Almost Always
41. I cooperate with other students when doing assignment work.	-2	-1	0	1	2
42. I share my resources with other students when doing assignments.	-2	-1	0	1	2
43. When I work in groups in this class, there is teamwork.	-2	-1	0	1	2
44. I work with other students on projects in this class.	-2	-1	0	1	2
45. I learn from other students in this class.	-2	-1	0	1	2
46. I work with other students in this class.	-2	-1	0	1	2
47. I cooperate with other students on class activities.	-2	-1	0	1	2
48. Students work with me to achieve class goals.	-2	-1	0	1	2

EQUITY	Almost Never	Seldom	Some-times	Often	Almost Always
49. The teacher gives as much attention to my questions as to other students' questions.	-2	-1	0	1	2
50. I get the same amount of help from the teacher as do other students.	-2	-1	0	1	2
51. I have the same amount of say in this class as other students.	-2	-1	0	1	2
52. I am treated the same as other students in this class.	-2	-1	0	1	2
53. I receive the same encouragement from the teacher as other students do.	-2	-1	0	1	2
54. I get the same opportunity to contribute to class discussions as other students.	-2	-1	0	1	2
55. My work receives as much praise as other students' work.	-2	-1	0	1	2
56. I get the same opportunity to answer questions as other students.	-2	-1	0	1	2

Appendix 5

PERMISSION TO USE TABLE 3.3

Re: Permission to use table

RG Rhiannon Giles <rgiles@wilderness.com.au>
Mon 22/11/2021 4:52 PM
To: Alice Dunlop

Dear Alice,

Thank you for your email. I am very happy for you to use the table in your thesis.

Kind regards,
Rhiannon

WILDERNESS SCHOOL
ALWAYS True

Rhiannon Giles
Head of House Cedar

+61 8 8343 1062
rgiles@wilderness.com.au
www.wilderness.com.au
30 Hawkers Road, Medindie, SA 5081

CRICOS Code: 00375B

From: Alice Dunlop <alice.gill@postgrad.curtin.edu.au>
Sent: Monday, 22 November 2021 4:04 PM
To: Rhiannon Giles <rgiles@wilderness.com.au>
Subject: Permission to use table

Dear Rhiannon,

I am seeking permission to use an adpated version of your Table 3.3 in my thesis. I will acknowledge this in the caption and references. Please see below the adapted table that I will be using in my thesis.

Table 3.4 Scale Description, Sample Item and Moos Schema for Each Scale in the What Is Happening In this Class? (WIHIC) Questionnaire

Scale Name	Scale Description	Sample Item	Moos' Schema
Student Cohesiveness	The extent to which students know, help and are supportive of one another.	In this class, I get help from other students.	R
Teacher Support	The extent to which the teacher helps, befriends, trusts and is interested in the students.	The teacher talks with me.	R
Involvement	The extent to which students have attentive interest, participate in discussions, do additional work and enjoy the class.	I discuss ideas in class	R
Investigation	The extent to which skills and processes of inquiry and their use in problem solving and investigations are emphasised.	I find out answers to questions by doing investigations	P
Task Orientation	The extent to which it is important to complete activities planned and to stay on the subject matter.	I know how much work I have to do.	P
Cooperation	The extent to which students cooperate rather than compete with one another on learning tasks.	I learn from other students in this class.	P
Equity	The extent to which students are treated equally by the teacher.	I get the same opportunity to answer questions as other students.	S

Note: R – Relationship, P – Personal Development, S – System Maintenance and System Change.
All items are scored 1, 2, 3, 4 and 5, respectively, for the responses of Almost Never, Seldom, Sometimes, Often and Almost Always.
This table is adapted from Giles (2019) with her permision (see Appendix 5).

Please let me know if you approve.

Kind regards,

Alice Dunlop

Reply | Forward

Appendix 6

INTERVIEW SCHEDULE- PHASE 3, STAGE 1

Interview Schedule

Phase 3- Stage One

Questions based on primary school:

1. In primary school, did you have your science lessons in a science laboratory or in the classroom?
2. In primary school, did your science teacher teach you for any other subject areas or just science?
3. In your primary school, did your science teacher motivate you or make you passionate about science? If so, how?
4. In your primary school, how many minutes were dedicated to science in one week?
5. Do you hope to pursue career in science in the future? Why/why not?
6. Do your parents have a career in science?
7. Did you enjoy your science lessons in primary school? Why/why not?
8. In primary school, did your teacher help you in science and show interest in what you were doing?
9. In primary school, did the other students in your science class help and support you when needed?
10. In primary school, were you given the opportunity to take part in class discussions during science lessons?
11. In primary school, did you do a lot of experiments to find an answer to a question, or did the teacher give you the answer?
12. What do you think about scientists?
13. Do you enjoy doing scientific investigations and inquiries? Why/why not?

Questions- based on current Secondary School

1. At your current school, do you have your science lessons in a science laboratory or in the classroom?
2. At your current school, does your science teacher teach you for any other subject areas or just science?
3. At your current school, does your science teacher motivate you or make you passionate about science? If so, how?
4. At your current school, how many minutes are dedicated to science in one week?
5. Do you hope to pursue career in science in the future? Why/why not? Has your opinion changed since our last interview?
6. Do your parents have a career in science?
7. At your current school, do you enjoy your science lessons? Why/why not?
8. At your current school, does your teacher help you in science and show interest in what you are doing?
9. At your current school, do the other students in your science class help and support you when needed?
10. At your current school, are you given the opportunity to take part in class discussions during science lessons?
11. At your current school, do you do a lot of experiments to find an answer to a question, or does the teacher give you the answer?
12. What do you think about scientists? Has your opinion changed since your last interview?
13. Do you enjoy doing scientific investigations and inquiries? Why/why not? Has your opinion changed since your last interview?

Appendix 7

INTERVIEW SCHEDULE- PHASE 3, STAGE TWO

Curtin University

Interview Schedule

Phase 3- Stage Two

1. Do you like science lessons - why and why not?
2. What is the best thing about science lessons?
3. Does the teacher make the lessons interesting?
4. What would make them more interesting?
5. How could you be encouraged to like science more?
6. What do you dislike about science?
7. Are you interested in science and do you do anything out of school that is related to science?
8. Would you be interested in doing something related to science when you leave school (job) why or why not?
9. The data from the surveys show that girls perceive the learning environment more positively in a coeducation school. Why do you think that is the case?
10. The data from the surveys show that boys have more positive attitudes towards science than girls. Why do you think that is the case?

Appendix 8

CURTIN UNIVERSITY ETHICS APPROVAL

Curtin University

Memorandum

To	Alice Gill, SMEC
From	Pauline Howat, Administrator, Human Research Ethics Science and Mathematics Education Centre
Subject	Protocol Approval **SMEC-52-12**
Date	13 December 2012
Copy	Jill Aldridge, SMEC

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 Low Risk (Ethical Requirements)" for the project titled *"Investigating the relationships between science classroom environment, student attitudes and student achievement as student's transition from primary school to secondary school"*. 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 **10th December 2012** to **9th December 2013**.

The approval number for your project is **SMEC-52-12**. *Please quote this number in any future correspondence*. If at any time during the twelve months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately.

Pauline Howat.

PAULINE HOWAT
Administrator
Human Research Ethics
Science and Mathematics Education Centre

Please Note: The following standard statement must be included in the information sheet to participants:
This study has been approved under Curtin University's process for lower-risk Studies (Approval Number SMEC-52-12). This process complies with the National Statement on Ethical Conduct in Human Research (Chapter 5.1.7 and Chapters 5.1.18-5.1.21).
For further information on this study contact the researchers named above or the Curtin University Human Research Ethics Committee. c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth 6845 or by telephoning 9266 9223 or by emailing hrec@curtin.edu.au.

J:\SAE\SMEC\office\Pauline\ETHICS\Ethics Approval Letter 2012\Gill.docx

CRICOS Provider Code 00301J

Appendix 9

DECD APPROVAL

COPY

Government of South Australia
Department for Education and Child Development

Policy and Communications

Level 8
31 Flinders Street
Adelaide SA 5000
GPO Box 1152
Adelaide SA 5001
DX 541

Tel: 8226 4108
Fax: 8226 1605

DECD CS/13/199.2

18 February 2013

Ms Alice Gill
Marymount College
8 Colton Ave
HOVE SA 5048

Dear Ms Gill

Your project titled "Investigating the relationships between science classroom environment, student attitudes and student achievement as students transition from primary school to secondary school." has now been reviewed by a senior Department for Education and Child Development (DECD) consultant with respect to protection from harm, informed consent, confidentiality and suitability of arrangements. Accordingly, I am pleased to advise you that your project has been **approved.**

The DECD Reviewer of this project is Tina Delchau. If you wish to clarify or discuss further please feel free to contact her on Ph: 8226 4142

Please contact Ms Allison Cook, Project Officer - Research and Innovation on (08) 8226 4108 for any other matters you may wish to discuss regarding the general review/approval process.

Please supply the department with an electronic copy of the final report which will be circulated to interested staff and then made available to DECD educators for future reference.

I wish you well with your project.

Lesie C. Mincham
for

Ben Temperly
HEAD OF POLICY AND COMMUNICATIONS

COPY

Government of South Australia
Department for Education and Child Development

Policy and Communications

31 Flinders Street
Adelaide SA 5000
GPO Box 1152
Adelaide SA 5001
DX 541

Tel: 8226 4108
Fax: 8226 1605

DECD CS/13/199.2

Dear Principal/Director/Site Manager

The research project titled *"Investigating the relationships between science classroom environment, student attitudes and student achievement as students transition from primary school to secondary school." has been reviewed* centrally and granted approval for access to Department for Education and Child Development (DECD) sites. However, the researcher will still need your agreement to proceed with this research at your site.

Once approval has been given at the local level, it is important to ensure that the researchers fulfil their responsibilities in obtaining informed consent as agreed, that individuals' confidentiality is preserved and that safety precautions are in place.

Researchers are encouraged to provide feedback to sites used in their research, and you may wish to make this one of the conditions for accessing your site. To ensure maximum benefit to DECD, researchers are also asked to supply the department with a copy of their final report which will be circulated to interested staff and educators for future reference.

Please contact Allison Cook, Project Officer – Research and Innovation on (08) 8226 4108 for further clarification if required, or to obtain a copy of the final report.

Yours sincerely

Ben Temperly
HEAD OF POLICY AND COMMUNICATIONS

Appendix 10

CESA APPROVAL

Catholic Education Centre

116 George Street Thebarton SA 5031
PO Box 179 Torrensville Plaza South Australia 5031
Telephone: (08) 8301 6600
Facsimile: (08) 8301 6611
ISD: 61 8 8301 6600
Email: director@cesa.catholic.edu.au

www.cesa.catholic.edu.au

Ms Alice Gill c/- Curtin University
Email: agill@mc.catholic.edu.au

Dear Ms Gill

Thank you for your recent email correspondence in which you seek permission to approach Catholic schools in South Australia regarding participation in the research study *Investigating the relationships between science classroom environment, student attitudes and student achievement as student's transition from primary school to secondary school.* I understand the study will involve students in Year 8 complete two surveys at the beginning and middle of the year, and that one student from each participating school will participate in two in-depth interviews.

In the normal course, permission of the Principal of each school in which you wish to conduct research is required. Research in Catholic schools is granted on the basis that individual students, schools and the Catholic sector itself is not specifically identified in published research data and conclusions.

Approval is also contingent upon the following conditions, i.e. that:

- a copy of the surveys has been provided to the Principal
- the permission of parents has been obtained
- the research complies with the ethics proposal of the University
- the research complies with any provisions under the Privacy Act that may require adherence by you as researcher in gathering and reporting data
- no comparison between schooling sectors is made

- **the researcher will be carrying out the research within view of the class teacher or authorised school observer**
- sector requirements relating to child protection and police checks are met by researchers:

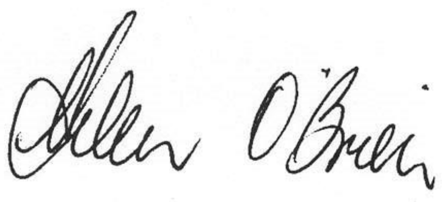
  ○ where researchers obtain information in relation to a student which suggests or indicates abuse, this information must be immediately conveyed to the Director of Catholic Education SA ○ all researchers and assistants, who in the course of the research interact in any way with students, are required to undertake a police check through the Archdiocese of Adelaide Police Check Unit.

Information with regard to obtaining police clearance can be accessed at the website address: www.cesa.catholic.edu.au

Researchers should forward a certified copy of their National Police Certificate, which has been issued within the last three months, to the Catholic Archdiocese of Adelaide Police Check Unit at the Catholic Education Office, PO Box 179, Torrensville Plaza SA 5031. The Police Check Unit will then post a clearance letter to the researcher. This letter should be provided to the Principal of each school.

Please accept my very best wishes for the research process.

Yours sincerely



HELEN O'BRIEN

DEPUTY DIRECTOR

22 January 2013

Appendix 11

STUDENT INFORMATION AND CONSENT FORM

PARTICIPANT INFORMATION SHEET

Curtin University

Science and Mathematics Education Centre

Dear Student,

Investigating the relationships between science classroom environment, student attitudes and student achievement as student's transition from primary school to secondary school

My name is Alice Gill and I am currently completing a piece of research for my Masters of Philosophy in Science and Mathematics Education at Curtin University.

Purpose of Research

I am investigating the relationship between science classroom environment and student attitudes and achievement as students' transition from primary school to secondary school.

Your Role

I am interested in finding out:

1. In what ways do student learning environment perceptions and attitudes differ in primary and secondary school?
2. What is the relationship between the science classroom environment and
    i. student attitudes; and
    ii. student achievement?

I will ask you to complete two surveys in the beginning weeks of the school year and the same two surveys in the middle of the school year. These surveys are to find out your perception of the classroom environment and your attitude towards science. The initial survey responses will be based on your experience of science at your previous school (primary school). The surveys administered in the middle of the year will be based on your experience of science at your current school (secondary school). Each survey will take approximately 45 minutes to complete.

I will be selecting one student from each school for in-depth interviews. These interviews should not take any longer than 1 hour and there will be two interviews throughout the year. If you are selected to take part in an interview and accept, you will be asked to respond to questions relating to the surveys that you have completed. These interviews will be audio recorded.

Consent to Participate

Your involvement in the research is entirely voluntary. You have the right to withdraw at any stage without it affecting your rights and 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

The information you provide will be kept separate from your personal details, and only myself and my supervisor will only have access to this. The interview transcript and recording will not have your name or any other identifying information on it and in adherence to university policy, the interview tapes and transcribed information will be kept in a locked cabinet for at least five years, before a decision is made as to whether it should be destroyed.

Further Information

This research has been reviewed and given approval by Curtin University Human Research Ethics Committee (Approval Number SMEC-52-12). If you would like further information about the study, please feel free to contact me on 0412763430 or by email agill@mccatholic.edu.au. Alternatively, you can contact my supervisor Jill Aldridge on +618 9266 3592 or by email j.aldridge@curtin.edu.au. Any complaints regarding ethical issues should be directed to the Human Research Ethics Committee (Secretary) on +61 8 9266 2784 or hrec@curtin.edu.au or in writing C/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, WA, 6845.

Thank you very much for your involvement in this research. Your participation is greatly appreciated.

CONSENT FORM

Project title:

Investigating the relationships between science classroom environment, student attitudes and student achievement as student's transition from primary school to secondary school

I understand the purpose and procedures of the study.

I have been provided with the participation

information sheet. I understand that the procedure

itself may not benefit me.

I understand that my involvement is voluntary and I can withdraw at any time without problem.

I understand that no personal identifying information like my name and address will be used in any published materials.

I understand that all information will be securely stored for at least 5 years before a decision is made as to whether it should be destroyed.

I have been given the opportunity to ask questions about

this research. I agree to participate in the study outlined to

me.

Name:____

Signature:____

Date:____

Appendix 12

STUDENT INFORMATION AND CONSENT FORM

Research Title: Learning Environment Perceptions and Attitudes towards Science: Examining Gender Differences and Differences for Girls in Coeducational and Single Sex

STUDENT INFORMATION SHEET

My name is Alice Dunlop and I am currently completing a piece of research for my Doctor of Philosophy in Science and Mathematics Education at Curtin University of Technology.

Purpose of Research

The overarching aim of my study is to examine learning environment perceptions and attitudes towards science as student's transition from primary to secondary school and whether differences exist for boys and girls in coeducational schools and for girls in single sex and coeducational schools.

Your role:

I am interested in finding out:

1. Whether differences exist for girls and boys enrolled in coeducational schools in terms of their:
    a. perceptions of the learning environment; and
    b. attitudes towards science.
2. Whether differences exist for co-educational and single sex schools in terms of students':
    a. perceptions of the learning environment; and
    b. attitudes towards science.

I have already surveyed 204 Year 8 students from 10 secondary schools and have interviewed 21 students from 6 of the 10 schools who were surveyed. However, I need to find out more information about the differences that exist for females in an all-girls school compared with a co-education school. To seek further information, I will need to interview female students from both single-sex and co-education schools. These interviews should not take any longer than 30 minutes. When scheduling these interviews, I will aim to schedule them outside of class time so no lessons are missed. Students will be asked to respond to questions relating to attitudes towards science. These interviews will be audio recorded.

Consent to Participate

The student's involvement in the research is entirely voluntary. They have the right to withdraw at any stage without it affecting their rights and responsibilities. When the student and parent/guardian have signed the consent form I will assume that both student and parent/guardian have agreed for the student to participate and allow me to use their data in this research. If the student wishes to withdraw from this study, I will destroy their data and not use it in my research.

Confidentiality

The information you provide will be kept separate from your personal details, and only myself and my supervisor will only have access to this. The interview transcript and recording will not have your name or any other identifying information on it and in adherence to university policy, the interview tapes and transcribed information will be kept in a locked cabinet for at least five years, before a decision is made as to whether it should be destroyed.

Further Information

This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval Number: SMEC-52-12). If you would like further information about the study, please feel free to contact me by email gill0183@gmail.com. Alternatively, you can contact my supervisor Jill Aldridge by email j.aldridge@curtin.edu.au.

CONSENT FORM

I UNDERSTAND THE PURPOSE AND PROCEDURES OF THE STUDY.

I have been provided with the participation information sheet. I

understand that the procedure itself may not benefit me.

I understand that my involvement is voluntary and I can withdraw at any time without problem.

I understand that no personal identifying information like my name and address will be used in any published materials.

I understand that all information will be securely stored for at least 5 years before a decision is made as to whether it should be destroyed.

I have been given the opportunity to ask questions about this research. I

agree to participate in the study outlined to me.

Name:____

Student Signature:____

Thank you very much for your involvement in this research. Your participation is greatly appreciated

Appendix 13

PARENT INFORMATION AND CONSENT FORM

PARENT INFORMATION SHEET

Science and Mathematics Education Centre

Dear Parent/s,

Investigating the relationships between science classroom environment, student attitudes and student achievement as student's transition from primary school to secondary school

My name is Alice Gill and I am currently completing a piece of research for my Masters of Philosophy in Science and Mathematics Education at Curtin University.

Purpose of Research

I am investigating the relationship between science classroom environment and student attitudes and achievement as students' transition from primary school to secondary school.

Your Role

I am interested in finding out:

1. In what ways do student learning environment perceptions and attitudes differ in primary and secondary school?
2. What is the relationship between the science classroom environment and
   i. student attitudes; and
   ii. student achievement?

I will ask your daughter/son to complete two surveys in the beginning weeks of the school year and the same two surveys in the middle of the school year. These surveys are to find out their perception of the classroom environment and their attitude towards science. The initial survey responses will be based on your daughter/son's experience of science at their previous school (primary school). The surveys administered in the middle of the year will be based on their experience of science at their current school (secondary school). Each survey will take approximately 45 minutes to complete.

I will be selecting one student from each school for in-depth interviews. These interviews should not take any longer than 1 hour and there will be two interviews throughout the year. If your daughter or son are selected to take part in an interview and accept, they will be asked to respond to questions relating to the surveys that they have completed. These interviews will be audio recorded.

Consent to Participate

Your daughter/son's involvement in the research is entirely voluntary. They have the right to withdraw at any stage without it affecting their rights and responsibilities. When you have signed the consent form I will assume that you have agreed for your daughter or son to participate and allow me to use their data in this research.

Confidentiality

The information your daughter or son provide will be kept separate from your personal details, and only myself and my supervisor will only have access to this. The interview transcript and recording will not have their name or any other identifying information on it and in adherence to university policy, the interview tapes and transcribed information will be kept in a locked cabinet for at least five years, before a decision is made as to whether it should be destroyed.

Further Information

This research has been reviewed and given approval by Curtin University Human Research Ethics Committee (Approval Number SMEC-52-12). If you would like further information about the study, please feel free to contact me on 0412763430 or by email agill@mccatholic.edu.au . Alternatively, you can contact my supervisor Jill Aldridge on +618 9266 3592 or by email j.aldridge@curtin.edu.au. Any complaints regarding ethical issues should be directed to the Human Research Ethics Committee (Secretary) on +61 8 9266 2784 or hrec@curtin.edu.au or in writing C/-

Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, WA, 6845.

Thank you very much for your involvement in this research. Your participation is greatly appreciated.

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Science and Mathematics Education Centre

CONSENT FORM

PROJECT TITLE

Investigating the relationships between science classroom environment, student attitudes and student achievement as student’s transition from primary school to secondary school

I understand the purpose and procedures of the study.

I have been provided with the participation

information sheet. I understand that the procedure

itself may not benefit me.

I understand that my child’s involvement is voluntary and they can withdraw at any time without problem.

I understand that no personal identifying information like my child’s name and address will be used in any published materials.

I understand that all information will be securely stored for at least 5 years before a decision is made as to whether it should be destroyed.

I have been given the opportunity to ask questions about

this research. I agree to participate in the study outlined to

me.

Name:____

Signature:______________________________________

Date:__________________________

Appendix 14

TEACHER INFORMATION AND CONSENT FORM

TEACHER INFORMATION SHEET

Science and Mathematics Education Centre

Dear Teacher,

Investigating the relationships between science classroom environment, student attitudes and student achievement as student's transition from primary school to secondary school

My name is Alice Gill and I am currently completing a piece of research for my Masters of Philosophy in Science and Mathematics Education at Curtin University.

Purpose of Research

I am investigating the relationship between science classroom environment and student attitudes and achievement as students' transition from primary school to secondary school.

Your Role

I am interested in finding out:

1. In what ways do student learning environment perceptions and attitudes differ in primary and secondary school?
2. What is the relationship between the science classroom environment and
   i. student attitudes; and
   ii. student achievement?

I will ask you to administer two surveys in the beginning weeks of the school year and the same two surveys in the middle of the school year. These surveys are based on classroom environment and attitudes towards science. The initial survey responses will be based on the student's previous school (primary school). The surveys administered in the middle of the year will be based on the student's current school (secondary school). Each survey will take approximately 45 minutes each. I will also ask you to provide an end of semester science grade and a one sentence comment in regards to the student attitude and participation in science lessons for each student who participated in the surveys.

I will be selecting one student from each school for in-depth interviews. These interviews should not take any longer than 1 hour and there will be two interviews throughout the year. If you one of your students is selected to take part in an interview and accept, they will be asked to respond to questions relating to the surveys that they completed. These interviews will be audio recorded.

Consent to Participate

The student's involvement in the research is entirely voluntary. They have the right to withdraw at any stage without it affecting their rights and responsibilities. When they have signed the consent form I will assume that they have agreed to participate and allow me to use their data in this research.

Confidentiality

The information students provide will be kept separate from their personal details, and only myself and my supervisor will only have access to this. The interview transcript and recording will not have your name or any other identifying information on it and in adherence to university policy, the interview tapes and transcribed information will be kept in a locked cabinet for at least five years, before a decision is made as to whether it should be destroyed.

Further Information

This research has been reviewed and given approval by Curtin University Human Research Ethics Committee (Approval Number SMEC-52-12). If you would like further information about the study, please feel free to contact me on 0412763430 or by email agill@mccatholic.edu.au . Alternatively, you can contact my supervisor Jill Aldridge on +618 9266 3592 or by email j.aldridge@curtin.edu.au. Any complaints regarding ethical issues should be directed to the Human Research Ethics Committee (Secretary) on +61 8 9266 2784 or hrec@curtin.edu.au or in writing C/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, WA, 6845.

Science and Mathematics Education Centre

CONSENT FORM

Project title:

Investigating the relationships between science classroom environment, student attitudes and student achievement as student's transition from primary school to secondary school

I understand the purpose and procedures of the study.

I have been provided with the participation

information sheet. I understand that the procedure

itself may not benefit me.

I understand that my involvement is voluntary and I can withdraw at any time without problem.

I understand that no personal identifying information like my name and address will be used in any published materials.

I understand that all information will be securely stored for at least 5 years before a decision is made as to whether it should be destroyed.

I have been given the opportunity to ask questions about

this research. I agree to participate in the study outlined to

me.

Name:____

Signature:____

Date: