Science and Mathematics Education Centre

Gifted Females' Attitudes and Perceptions of Learning Environment in Technology-Based Science Classrooms in Singapore

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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 which has been accepted for the award of any other degree or diploma in any university.

Human Ethics (For projects involving human participants/tissue, etc) 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-33-13.

Signature: ____________________

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Date: September 2016

ABSTRACT

This study was the first in the Singapore context to focus on gifted female students in technology-based science classrooms in a secondary school setting. The study's aims were to investigate the validity and reliability of a learning environment and an attitude questionnaire for gifted female students in a secondary school in Singapore, differences between technology-based science classrooms and regular science classrooms in terms of students' attitudes and perceptions of classroom learning environment and associations between students' perceptions of their classroom learning environments and attitudes.

A learning environment and attitude questionnaire was administered to 379 students from 14 technology-based science classrooms and 343 students from 13 regular science classrooms. The responses from the 722 students were analysed for factor structure. Internal consistency reliability, discriminant validity and ability to differentiate between classes were also calculated. To investigate differences between technology-based science classrooms and regular science classrooms in terms of students' attitudes and perceptions, MANOVA/ANOVAs and effect sizes were used. To investigate the associations between students' perceptions of their classroom environments and attitudes, simple correlation and multiple regression analyses were also conducted.

Statistical analyses of data from this study suggested that the questionnaire is valid and reliable for appraising students' perceptions of the learning environment and their attitudes when used with gifted female students at a secondary school in Singapore. The learning environment and attitude scales for which differences between technology-based and regular classes were statistically significant (Investigation, Task Orientation, Collaboration, Computer Usage, Formative Assessment, Attitudes towards Computers and Self-regulation), the effect sizes were 0.36, 0.40, 0.22, 1.09, 0.27, 0.37 and 0.31 standard deviations, respectively.

The simple correlations established that the relationships between learning environment and student attitudes were positive. The statistically significant multiple correlations also confirmed the impact of the learning environment on student attitudes. However, there was negligible difference between technology-based and regular classes in the strength and direction of associations between students' perceptions of their classroom learning environments and attitudes.

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I thank the Principal and teachers of the school where the study was carried out and all the participants in this study who have spent the time to provide their candid responses. My gratitude also goes to the parents of the participants who have been supportive of my study and allowed their daughters to contribute in this study.

DEDICATION

I would like to dedicate this work to LORD VINAYAGAR who has showed me the path and been my constant guide and strength throughout my course. HE has given me courage and the tenacity to face many challenges in my learning journey. HE has directed me to make the best decisions, removed obstacles and showed me the way when I encountered difficulties.

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RATIONALE AND BACKGROUND

1.1 Introduction

Society benefits by developing gifted and talented students' potential because they are a country's human resource and will become tomorrow's prominent scientists, political leaders, innovative engineers and business entrepreneurs. Most past research on gifted learners has focused on the relationship between IQ and academic achievement, cognitive thinking and moral reasoning, as well as identification and programming for the education of the gifted. There have been a few studies of the experiences of gifted students in science learning environments fand even fewer studies of the outcomes of using technologies in the science classroom for the gifted. "Because students spend 20,000 classroom hours by the time they graduate from the university" (Fraser, 2001, p. 1), their educational experiences in the classroom environment are significant and more attention is required in this area.

So far, there have been about 13 studies undertaken on learning environments and attitudes in the Singapore school setting. Among them, only three have focused on gifted pupils (Caleon & Subramaniam, 2008; Peer & Fraser, 2015; Quek, Wong, & Fraser, 2005). Therefore, there is very limited published research on learning environments and student attitudes in gifted classrooms in Singapore schools that can inform practice. The findings in this research are likely to be valuable in providing feedback about the learning experiences of gifted female students in the science classroom and its influence on students' attitudes.

In a Singapore school for female gifted learners where I have been a science teacher for about 20 years, a new initiative known as the one-student one-laptop programme was introduced in 2012. This programme, a curriculum plan which aims to develop digital literacy in gifted girls, involves each student in owning a laptop computer and using it in the classroom for at least one-third of the curriculum time for each subject. The other goals of this programme are to develop students to become self-directed, responsible and participative members of the digital community.

The educators at this school are trained and encouraged to transform the teaching and learning process in the classroom by infusing the Information and Communication Technology (ICT) tool seamlessly in their instructional and assessment activities. This ICT tool, like any other tool, is believed to allow work to be done more effectively and efficiently. ICT expands the prospects in teaching and learning, facilitated by quick access to information, online social networking, and collaborative and communication platforms.

In this study, the technology-based classes comprised the pioneer cohort of students in the one-student one-laptop programme. These students have been consistently learning science for two and a half years while using the laptop as a tool for learning. A typical lesson involves the students accessing different types of media, including text, videos, images, models, simulations and animations. Students may set their goals and targets and organise their learning with the use of wikis, blogs, online calendars and email. The students are encouraged to access online libraries, databases and search engines to learn independently and collaborate with their peers both within their class synchronously or beyond class asynchronously. The students can create digital products using video-editing software, slideshows, animations and websites to demonstrate their learning. The science teachers provide lesson materials such as Powerpoints, Google Sheet and Google Docs using online platforms such as Edmodo and Google Domain, and they conduct surveys and quizzes online to gather information on students' knowledge. In science practical lessons, students are able to use electronic probes to collect data on light intensity, pH and humidity, and to share and compare real-time data with classmates or schoolmates. After lessons, students can access teachers and experts without having to meet them face-to-face, submit work online and receive timely feedback from peers, teachers and experts.

On the other hand, in the regular science classes, the students did not bring a laptop to school and they had been learning science in the last three and a half-years using hard-copy lesson materials such as textbooks, worksheets and notes. A typical lesson would be one in which the science teachers used Powerpoint slides and internet sources such as videos and animation in their instruction. Students did not have access to any online platforms in science lessons, collaboration with their peers was undertaken within class synchronously, and all student work was submitted as hard-copies.

In summary, the type of curriculum and the experience of science teachers were similar in technology-based and regular classes, but the pedagogy employed was different (as described above).

In the science classrooms, inquiry-based learning is highly encouraged and, with the introduction of laptop computers, the school aims to provide a learning environment that promotes self-directed and collaborative learning, critical and creative thinking skills, research skills, problem-solving skills, differentiation and feedback on learning. A lot of money, time and effort are invested by science teachers in planning, designing and implementing a coherent technology-based science module for classrooms. However, there is not enough empirical evidence about whether the aspired characteristics of the classroom environment appropriate for nurturing the brightest students exist and the impact of technology on the gifted students. Therefore the overarching objective of this study was to assess the impact of the new one-student one-laptop programme on the psychosocial learning environment and attitudes of gifted girls in science classrooms. The attitudes of students in both types of classrooms were compared and associations between the learning environment and attitudes were analysed. This study is pertinent and unique because it is the first Singaporean research on secondary-school gifted female students in science classrooms where technology is used in instruction.

The rest of this chapter provides background information on the current study, such as its context, theoretical framework, research objectives and significance.

Section 1.2 presents the setting of Singapore and the school for the gifted where this study was conducted. Section 1.3 describes the theoretical framework relevant to the study. Section 1.4 states the specific research objectives. Section 1.5 addresses the significance of the research. Lastly, Section 1.6 provides an overview of the organisation of the remaining chapters comprising this thesis.

1.2 Context of Study

This section provides a general outline of the country, namely, Singapore (Section 1.2.1), and the school for the gifted (Section 1.2.2) where the study was conducted.

1.2.1 Overview of Singapore

Singapore is a small city state in Southeast Asia, situated at the southern end of the Malay Peninsula between Malaysia and Indonesia. It was part of Malaysia but gained independence as a sovereign state in 1965. This second smallest country in Asia has a total land area of 714.3 square kilometres and population size of 5.47 million. Singapore has no physical natural resources and relies solely on human resources as the only available natural resource. However, this resource is limited by the small population size. The economy and continual success of the country depends on how well it develops the human capital. To this end, Singapore's Ministry of Education (MOE) formulated the Gifted Education Programme (GEP) in 1984. The goal of this programme is to develop intellectually-gifted pupils among the population with the hope that these talented people would one day become future leaders and continue to develop the economy in Singapore. Hence, the GEP is considered to be beneficial to the long-term interest and survival of the country as it caters to the nurturing of the academically-brightest in the nation, thereby optimising the limited human resources available in Singapore (Ministry of Education, 2016b).

1.2.2 Overview of the School for the Gifted

Singapore's MOE conducts a regular review of the curriculum to ensure that the pupils will develop the 21st Century competencies necessary for the workplace. The education system's effort to shift its focus from quantity to quality in education is evident in Singapore's performance in the Programme for International Student Assessment (PISA) in 2012 and 2015. The country was ranked second in 2012 and first in 2015 in Mathematics, Reading and Science. Singapore's mean score in Science was 551 in 2012, which was above the international average score of 501. In 2015, the mean score in Science increased to 556 when the international average score was 493.

The school that was selected in the present study is a centre of education excellence, attracting the best and the brightest girls in Singapore and around the world. It is one of the top-ranking girls' school for high-ability learners.

The GEP conceptualised by the MOE was piloted in January 1984 in two primary and two secondary schools. In 1983, 4% of students with top scores in the Primary School Leaving Examination (PSLE) sat for three intelligence tests. Based on the tests, students were ranked and those in the top 1% were selected for the pilot programme in the secondary schools. MOE channeled more funding to the pilot schools for designing and providing an enrichment programme to develop the best and the brightest in the nation to their fullest potential. The best teachers with suitable qualities to nurture the gifted were specially identified and trained to teach the gifted students.

In 2004, the MOE introduced the Integrated Programme (IP) in a few top-ranking schools and junior colleges. The IP allows academically-bright and university-bound students to bypass the GCE Ordinary Level (O-level) examination (commonly completed by students at the final year in secondary school) and progress, after six years of secondary and pre-university education, to take the GCE Advanced Level (A-level) examination or the International Baccalaureate

(IB). The students sit for the A-level examination after a two or a three year course in the junior college or pre-university institutes, respectively.

The school in the present research study was identified by the MOE for offering the IP and using the time freed up by not having to prepare for the GCE O-level examination to stretch its pupils and provide a more holistic curriculum in both academic and non-academic areas. The school now conducts its own school-based assessments to monitor its pupils' progress. The students of this school are admitted based on their high PSLE scores and Direct Admission Exercise conducted by the school. They are academically-bright girls in the top 3% of their cohort. Thirty percent of the students admitted are also from the Gifted Education Programme in their primary schools. Because the students are high-ability learners, the school adopts the Integrated Curriculum Model (Van Tassel-Baska, 1987) for the gifted as a school-wide framework for designing and implementing the curriculum.

1.3 Theoretical Framework

This section briefly describes the background relevant to this study. Section 1.3.1 includes a brief history of giftedness and gifted education and Section 1.3.2 describes briefly the history of the field of learning environments.

1.3.1 History of Giftedness and Gifted Education

In China and as early as in A.D. 618, gifted child prodigies were highly valued. They were identified and sent to the imperial court to nurture their special abilities. Ancient China anticipated the modern principles of gifted education which are adopted by many educational institutions all over the world today.

Empirical studies of giftedness started in the early twentieth century by pioneers in this field such as Francis Galton, Alfred Binet, Lewis Terman and Leta Hollingworth. Their studies brought scientific credibility to the field of gifted education and the realisation that the existing school systems were not adequately meeting the needs of all children. A strong emphasis in gifted education was fueled again by the late 1950s by the launching of Russia's satellite, Sputnik.

In 1983, the national report called Nation At Risk revealed that many bright pupils in America failed to compete with their peers in many other countries (National Association for Gifted Children, 2008). The gifted education policies, principles and standards were reviewed and a suitable curriculum was designed to meet the needs of the gifted learners. The gifted movement became worldwide and currently most countries (including Australia, Germany, China, India, Singapore and many others) have gifted programmes of various types. In Australia, there were isolated attempts by different states to provide special education for the academically gifted in the 1970s. But it was not until the late 1990s that gifted education policies based on credible educational and psychological theories were established, and provisions for programming for the gifted and talented were carefully planned and implemented in schools (Gross, 1999).

Although there is plenty of research literature and biographical and anecdotal accounts about giftedness and gifted education, there have been few studies into the experiences of gifted female students in science learning environments and even fewer studies of the learning experiences and attitudes of gifted students in technology-based science classrooms. So my research is important and unique.

A comprehensive review of literature for the field of gifted education can be found in Chapter 2, Section 2.2.

1.3.2 History of the Field of Learning Environments

Studies of educational environments stem from early contributions by human psychologists, Kurt Lewin, Henry Murray and their proponents. Lewin (1936) theorised that $B = f(P, E)$, where Behaviour (B) is a function (f) of the person (P) and his/her environment (E). Murray (1938) developed Lewin's theory further to include the idea of personal needs of an individual and environmental press. This needs–press theory then led to the development of various measures for personality studies. Though Lewin's theory and Murray's needs–press model were known in the 1930s, for many decades, research on the person and environment remained as two separate areas in educational psychology (Fraser & Fisher, 1983b). A method to assess the socio-emotional climate in the classrooms was first developed by Withall (1949) to classify and observe elements of interactions in the classroom using trained observers.

Research on the person–environment fit as a key determinant of students' classroom functioning and achievement only began in the 1970s, many decades later, after Hunt's (1975) provocative review that criticised researchers' reluctance to include both the person and the environment within the same studies. Based on Murray's ideas, Stern (1970) theorized that the complementary combination of personal needs and environmental press enhances student outcomes.

Murray also contributed the concepts of *alpha press* and *beta press,* which were further developed by Stern, Stein and Bloom (1956) who distinguished the "terms of 'private' beta press, the idiosyncratic view that each person has of the environment, and 'consensual' beta press, the shared view that members of a group hold of the environment. Private and consensual beta press could differ from each other, and both could differ from the detached view of alpha press of a trained nonparticipant observer" (Fraser, 2012, p. 1194).

Getzels and Thelen (1960) were the first to propose a framework for analysing the classroom as a unique social system. A strong emphasis on inter-relationships and communications among all members of the classroom community when assessing classroom environments was recommended by Doyle (1979).

More studies on learning environments were fueled by two highly-influential independent studies by Herbert Walberg and Rudolf Moos. Walberg designed the Learning Environment Inventory (LEI) to evaluate Harvard Project Physics, a curriculum development project in USA (Walberg & Anderson, 1968). Moos

(1979) first designed social climate scales to be administered in psychiatric hospitals and correctional institutions, and this eventually guided the design of the Classroom Environment Scale (CES) (Moos & Trickett, 1974; Trickett & Moos, 1973).

Since the work spearheaded by Walberg and Moos, major research programmes have been conducted on classroom environment, including the conceptualisation and development of other learning environment instruments (Fraser, 1986, 1991, 1994, 1998a, 2012; Goh & Khine, 2002). In Netherlands, Wubbels and his colleagues used the Questionnaire on Teacher Interaction (QTI) to study teacher–student interaction in the classroom (Fraser & Walberg, 2005; Wubbels & Brekelmans, 1998; Wubbels & Levy, 1993). Later, similar studies were carried out in other countries including Australia, Brunei, Korea and Singapore (Goh & Fraser, 1998; Henderson, Fisher, & Fraser, 2000; Kim, Fisher, & Fraser, 2000; Quek et al., 2005; Scott & Fisher, 2004). In Australia, the first study of student-centred classroom environments began using the Individualised Classroom Environment Questionnaire (ICEQ, Fraser, 1990; Fraser & Butts, 1982).

Walberg and Anderson (1972) found that students' impressions of their classroom environments can be obtained during classroom time. Students' perceptions also tend to be more accurate and more useful if a larger sample is possible (Fraser, 1991).

A comprehensive review of literature from the field of learning environments is presented in Chapter 2, Section 2.3.

1.4 Instruments Used in the Study

The instruments used in my study were questionnaire surveys which have been used in numerous other studies internationally and have been found to be valid and reliable. These surveys are efficient for data collection with a large sample size and quantitative analysis. The learning environments of technology and regular science classrooms were assessed using scales from the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) developed by Dorman, Aldridge and Fraser (2006) and the Constructivist-Orientated Learning Environment Survey (COLES) designed by Aldridge, Fraser, Bell and Dorman (2012).

Students' attitudes were assessed using the Attitude and Efficacy Questionnaire (AEQ) designed by Aldridge and Fraser (2008) and the Students' Adaptive Learning Engagement in Science (SALES) questionnaire (Velayutham, Aldridge, & Fraser, 2011).

1.4.1 Learning Environment Questionnaire

To assess the present-day classroom that infuses ICT into the curriculum and its educational outcomes, Aldridge, Dorman and Fraser (2004) developed and validated a new contemporary classroom environment instrument, the TROFLEI, using a multi-trait–multi-method model. The questionnaire is an extension of the commonly-used learning environment instrument, the What Is Happening In this Class? (WIHIC) developed by Fraser, Fisher and McRobbie (1996). The TROFLEI includes the seven scales in the WIHIC, as well as three additional classroom environment dimensions: Differentiation, Computer Usage and Young Adult Ethos, which provide a focus on technology and outcomes-focused education. In other words, this instrument contains 10 scales with 8 items each. Comprehensive reviews of the WIHIC and the TROFLEI can be found in Sections 2.4.9 and 2.4.10 of Chapter 2. To identify the degree to which the classroom teacher caters to individual students' needs, a Differentiation scale from the Individualised Classroom Environment Questionnaire (ICEQ; Fraser, 1990) was included in the TROFLEI. The degree and the variety of ways in which computers are used in the classroom can be assessed using the Computer Usage scale. A Young Adult Ethos scale was included to assess opportunities provided by teachers for student self-directed learning. TROFLEI scales were suitable for measuring the learning experiences in gifted classrooms because they are aligned with the instructional processes proposed by Van Tassel-Baska (1986) to facilitate curriculum experiences for the gifted.

Because all the existing classroom environment questionnaires exclude scales related to the assessment of student learning, which are useful in informing learners of their progress in learning, one additional scale on assessment of student learning from the Constructivist-Orientated Learning Environment Survey (COLES) was incorporated in the learning environment questionnaire in my study. The COLES was designed by Aldridge et al. (2012) to inform teachers undertaking action research for the purpose of improving their classroom environments. This instrument contains mostly the scales from the WIHIC but includes scales which assess student learning. A detailed review of the COLES is found in Section 2.4.11 of Chapter 2.

1.4.2 Student Attitude Questionnaire

Past research shows that learning environments have an influence on students' attitudes (Fraser, 1998a; Walker, 2006). My study focused on four important aspects of students' attitudes: attitudes towards computers, task value, self-efficacy and self-regulation. The scale to assess attitude towards computers was taken from the Attitude and Efficacy Questionnaire (AEQ) designed by Aldridge and Fraser (2008). Research has shown that schools that provide students with opportunities to use computers promote positive attitudes towards their use (Mitra & Steffensmeier, 2000). The other three attitude scales in my study were from the Students' Adaptive Learning Engagement in Science (SALES) questionnaire, which was developed by Velayutham et al. (2011) to assess motivation and self-regulated learning in science. Reviews of the AEQ and SALES are found in Sections 2.6.1 and 2.6.2 of Chapter 2.

1.5 Research Objectives

The main research objective was to assess the impact of technology among gifted girls in science classrooms by investigating differences between technology-based science classrooms and regular classrooms in terms of students' attitudes and perceptions of classroom learning environment.

Therefore, my three research questions were:

- to investigate the validity and reliability of a learning environment and an attitude questionnaire for gifted female students in a secondary school in Singapore;
- to investigate differences between technology-based science classrooms and regular science classrooms in terms of students' attitudes and perceptions of classroom learning environment;
- to investigate associations between students' perceptions of classroom learning environments and their attitudes.

1.6 Significance of the Study

So far, there have been about 13 studies undertaken on learning environments in the Singapore school setting. Among them, only two studies by Quek et al. (2005) and Peer and Fraser (2015) have focused on gifted pupils. Therefore, there are very few past studies on learning environments in gifted classrooms in Singapore schools that can inform practice. The evidence in this research is likely to be valuable in providing feedback about the learning experiences of gifted female students in the science classroom and its influence on students' attitudes.

Higher funding is provided by the MOE for the schools with high-ability learners is higher because it is hoped that the needs of these students can be met and they can be developed to their fullest potential. However there is insufficient evidence about whether the desired features of the learning environment suitable for the gifted exist and if there are differences between technology-based and regular science classrooms. This is the first study in Singapore of secondary gifted female students in technology-based science classrooms.

This investigation is also likely to add value to the field of learning environments by cross-validating a learning environment questionnaire for gifted females in a secondary school in Singapore. This study is also significant in cross-validating an attitude questionnaire for the first time in Singapore, thereby providing opportunities for this newly-developed instrument to be used in evaluating desirable outcomes in gifted classrooms in future research.

1.7 Overview of Thesis Chapters

This thesis comprises five chapters. Chapter 1 described the context of the study, background information relevant to this study, and its theoretical underpinnings. The chapter also delineated the research objectives, explained the significance and overviewed the organisation of the thesis.

Chapter 2 provides a detailed literature review of topics relevant to the present study. The chapter begins with the history of the conception of giftedness and gifted education. Next it reviews literature about science education for the gifted, gifted education in Singapore, and the science curriculum for the gifted in Singapore. The chapter also describes the history of the field of learning environments. Various types of learning environment questionnaires are reviewed, giving a more comprehensive review of the questionnaires used in this research, such as the TROFLEI and COLES. Detailed reviews of the attitude questionnaires, the AEQ and SALES, are also provided in this chapter. The chapter concludes with a review of the different types of past research on learning environments, including associations of classroom environment with students' attitudes.

Chapter 3 describes the methodology employed in the present study, including the field-testing of the questionnaire, background and selection of study participants, ethical considerations, data collection, data storage and instruments used. The chapter concludes by describing how the data were statistically analysed to address the research questions.

Chapter 4 reports the results of the statistical analyses undertaken to answer each research question. This chapter reports analyses that support the validity and reliability of the questionnaire. This chapter also reports differences between technology-based science classrooms and regular science classrooms in terms of students' attitudes and perceptions of classroom learning environment. Finally, the findings of my investigation of relationships between student attitudes and the classroom learning environment are presented.

Chapter 5 concludes this thesis and presents a final summary. This chapter explains the importance of conducting the present study and identifies its substantive, methodological and practical contributions. Limitations of this study are highlighted, and suggestions for further research are recommended.

Chapter 2
LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to review the comprehensive literature that is related to my study in order to provide a clear understanding of gaps in the literature and therefore to justify the need for my study. The overarching purpose of my study was to assess the impact of technology among gifted girls in science classrooms by investigating differences between technology-based science classrooms and regular classrooms in terms of students' attitudes and perceptions of classroom learning environment. Also, associations between the learning environment and attitudes in both types of classrooms were investigated. Therefore, this chapter provides a detailed review of gifted education, learning environment and student attitudes, which are the three broad areas relevant to my study.

Section 2.2 focuses on the history of the field of gifted education including conceptions of giftedness, development of gifted education, the education system and gifted education in Singapore, and the science curriculum for the gifted. Section 2.3 focuses on the history of the field of learning environments. Section 2.4 reviews a range of learning environments questionnaires and their conceptualisation, development and validation, especially the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) and the Constructivist-Oriented Environment Survey (COLES) whose scales were selected for my study. Section 2.5 discusses the various types of past research involving learning environment. Section 2.6 provides a history of the field of student attitudes, including a review of the attitude questionnaires used in my study, namely, the Attitude and Efficacy Questionnaire (AEQ) and Students' Adaptive Learning Engagement in Science (SALES), and their conceptualisation, development and validation. Section 2.7 provides a summary of this literature review.

2.2 Gifted Education

The purpose of this section is to review gifted education, which is the first broad category related to my study. Section 2.2.1 focuses on the history of the field of gifted education, including conceptions of giftedness and the development of gifted education. Section 2.2.2 describes the history of gifted education and the current education system in Singapore. Section 2.2.3 provides an overview of the science curriculum for the gifted.

2.2.1 History of Giftedness and Gifted Education

Giftedness in the human race was recognised long before the nineteenth century in ancient civilisations such as in China, Turkey, Rome and Greece. The brightest people in these societies were identified and groomed for leadership positions (Silverman, 2013). During those early centuries, conceptions of giftedness were not confined to mean general academic abilities and talents in specific areas such as aesthetics, science and economics, but also included physical ability as a desirable 'gift'. Military skills were highly valued in ancient Sparta and all the boys at the age of seven were trained in the arts of combat and warfare. Greek boys of upper social class were favoured in Athens and sent to private schools to learn reading, writing, arithmetic, history, literature, the arts and physical fitness.

The first person who began a scientific study on giftedness was Englishman Francis Galton in 1869. He published a book called *Hereditary Genius* which created controversy and a breakthrough that spurred more scientific research in later years. Galton stated that intelligence was inherited through natural selection. In 1883, he wrote *Inquiries into Human Faculty* and explored the possibility of measuring intelligence. A year later, he created the first mental tests which were measures of sensory capacity (Boring, 1950). The psychology of individual differences and the quantitative analysis of human intelligence were two of the many legacies of Galton (Silverman, 2013).

French psychologist, Alfred Binet, and his research assistant, Victor Henri, published an original paper in 1896 entitled 'Individual Psychology' which concluded that differentiating normal individuals from gifted people using their sensory capacities was less reliable than using higher intellectual processes. They proposed a series of simple tests to assess mental capacities such as memory, imagination, understanding and will power, among others. Binet and Henri's work was the first step towards the creation of the first intelligence scale (Binet & Simon, 1905) which measured intelligence as a single numerical outcome.

In 1908, an American, Henry Herbert Goddard, who was greatly influenced by Francis Galton's seminal work on geniuses, traveled to Europe and studied with Binet in France. There, he was introduced to the Binet-Simon measurement scales. He was the first to translate the test into English and use it with mentally-retarded children in schools. He was satisfied with the test, popularised it by distributing copies of it to American educators and psychologist, and advocated its use in public schools throughout United States (Zenderland, 1998).

Whilst Goddard is regarded as the 'father' of intelligence testing in the United States, Lewis Terman is known as the 'father' of the gifted education movement. Terman modified the original Binet-Simon intelligence test into Stanford-Binet test in 1916, and subsequently revised it in 1937 and 1960 to suit the American population, forever changing intelligence testing and the face of American education. Terman adopted from the German psychologist, William Stern, a definition of 'intelligence quotient' (also known as the 'IQ') as the ratio between mental and chronological age multiplied by 100 (Sattler, 1992).

In 1939, David Wechsler, another American psychologist, proposed a different form of measuring intelligence because he felt that the previous instruments placed too much emphasis on verbal capacity and ignored vital attributes of individuals. His Wechsler-Bellevue test became popular, widely accepted and widely used for assessing intelligence in the USA. He revised the test in 1942 and published the Wechsler Intelligence Scale for Children in 1949 (Wechsler, 1949). This was updated in 1974.

In 1915, Terman wrote a paper entitled ‘The Mental Hygiene of Exceptional Children’ in which he stated that, though giftedness is inherited, it requires nurturing to reach its potential and, for this, schools should cater for the development of children with exceptional intelligence (Bernreuter, Miles, Tinker, & Young, 1942). He is also best known for initiating the longitudinal study of children with high IQs called the ‘Genetic Studies of Genius’ in 1921. Terman tracked children with extremely high IQs in childhood throughout their lives to ascertain if they had successful adult lives. Any child with an IQ above 140, which was deemed to be the highest intellectual range, was identified as gifted (Colangelo & Davis, 2003). Terman wrote that unusually precocious children were more likely to be generally successful in their careers and many received awards in recognition of their achievement. His findings dispelled the contrary opinion that gifted children are unwell and social misfits. Though many of the gifted children in Terman’s study did exceptionally well in their adulthood, a few did not. Terman attributed this to potential talent not being realised, lack of opportunity, personal obstacles and education (Terman, 1925).

Before Galton’s book, *Hereditary Genius*, was published in 1869, William Torrey Harris, superintendent of public schools for St. Louis, introduced education for the gifted and allowed rapid advancement through the curriculum every five weeks based on academic performance. Between the periods of 1901 to 1956, very few special schools and classes were started to support the education of gifted students. Most of these were spearheaded by Hollingworth, who also published the first textbook on gifted education entitled *Gifted Children: Their Nature and Nurture* (National Association for Gifted Children, 2008). Empirical studies of giftedness in the nineteenth century by Galton and Binet and early twentieth century by pioneers in this field such as Lewis Terman and Leta Hollingworth brought scientific credibility to the field of gifted education, together with the realisation that existing school systems were not adequately meeting the needs of all children.

A strong emphasis in gifted education was fueled again in America by the launching of Russia’s satellite, Sputnik, in 1957. Large amounts of money were channeled to identify the brightest and most-talented students for studying advanced mathematics, science and technology. This was short-lived because, in 1964, the Civil Rights Act placed emphasis on equal education for all. The next wave of interest in gifted education started in 1972 following the Marland Report, the first national report on gifted education by the USA Department of Education to the Congress of the United States. The first compelling national report on gifted and talented children stated that these children are deprived and can suffer psychological damage and permanent impairment of their abilities to function well. The report presented to the Congress of the United States urged schools to define giftedness broadly and to provide adequate educational services to the gifted (Colangelo & Davis, 2003).

In 1974, The Office of the Gifted and Talented housed within the U.S. Office of Education was given official status. Interest in catering for the educational needs of gifted and talented children heightened in the mid-1970s when funds were set aside to identify the gifted and to design and formalise an enriched and accelerated curriculum. However, in 1975, The Education for All Handicapped Children Act established a federal mandate to serve children with special education needs, but this did not include children with gifts and talents. Up until the early 1980s, the gifted movement took a step backwards because of the notion of equity, budget cuts and a lack of supportive teachers and administrators.

In 1983, a national report, entitled A Nation At Risk, disclosed that America's brightest were not doing as well as their international contemporaries. The report published policies and practices in gifted education and advocated specially-tailored programming for the gifted.

Gifted education in Russia began in 1958 soon after the success of its space programme. That year, the first physics and mathematics school was opened in Moscow (Yurkevich & Davidovich, 2009). Provision for the gifted by the Israeli state began in 1973 when the then Minister of Education recognised that each child had the right to develop his/her abilities and that it was the responsibility of the Ministry to conceptualise the framework and content to cater for the development of these bright children (Burg, 1992). In Australia, there were isolated attempts by different states to provide special education for the academically gifted in the 1970s. But it was not until the late 1990s that gifted education policies based on credible educational and psychological theories were established, and then provisions for programming for the gifted and talented was carefully planned and implemented in schools (Gross, 1999). By 1990s, the U.S. government enacted legislations and allocated funds for initiating educational programmes and services for gifted children. Content standards, curriculum and assessment practices were designed to challenge gifted children to develop their critical and creative thinking ability. The gifted movement has become worldwide and currently Australia, Germany, China, India, Singapore and many other countries have gifted programme of various types.

2.2.2 Gifted Education in Singapore

When the famous psychologist Leta Hollingworth (1940) extensively researched gifted children, she concluded that “the development of all the world's natural resources depends on human intelligence, courage, stamina and will. It depends primarily on *thinking.* Therefore, intellectually-gifted children are among the most valuable assets of a civilised nation” (p. 116).

Singapore is a small nation with no physical natural resources and whose economic and financial stability relies largely on its people. Since the country gained independence from Malaysia, the focus has been on educating the people, who are the country’s main resource. The education system in Singapore was first designed to provide each child with a basic education so that he or she could contribute to the economy of the country. In 1979, the New Education System was introduced to provide opportunities to develop every child’s potential to the limits of his or her abilities (National Library Board, 2016). In the New Education System, every student is encouraged to pace his/her learning because the Ministry of Education is committed to develop the potential of every student (National Library Board, 2016). So the Ministry designs and provides an education which is sound and relevant to allow individual development and assist students to reach their potential.

With the New Education System in place, there were concerns that the needs of intellectually-bright pupils were not being met and that their potential was not being realised with the existing curriculum framework. In 1981, when an entourage of educators, led by the then Minister of Education, Tay Eng Soon, visited Russia, Israel and West Germany to study their gifted programmes, they found that the Israeli model of having special classes within regular schools was the best fit for Singapore. A programme was proposed to provide for the intellectually gifted that aimed to develop higher-level thinking skills, self-directed learning, social responsibility and civic awareness (National Library Board, 2015).

This led to the introduction of the Gifted Education Programme (GEP) in Singapore schools in 1984. The GEP, when it first began, was a highly-selective academic programme designed to identify the 0.5% of students who were the most outstandingly intelligent from each academic year level. In Singapore, pupils are identified for the GEP based on their performance in selection tests, which are conducted at the end of Primary 3 (Grade 3). The pupils first sit for a screening test comprising two papers: English Language and Mathematics. About 4000 pupils are shortlisted to sit the GEP Selection Test comprising three papers: English Language, Mathematics and General Ability. Around 500 pupils are admitted into the GEP which is introduced in Primary 4 (Grade 4). These pupils have high intellectual ability and potential and so the curriculum is enriched and differentiated to cater for their development. This advanced curriculum is built on the regular curriculum, with the main advantage of the GEP being that it offers individualised enrichment and attention to gifted pupils. In Primary 6, GEP pupils sit the same Primary School Leaving Examination (PSLE) as mainstream pupils and get allocated to secondary schools based on their scores. Most of them gain admission into the best secondary schools with Integrated Programmes.

Besides developing “intellectual rigour, humane values and creativity in gifted youths” (Ministry of Education, 2016b, para. 6), one of the main reasons for implementing the GEP in Singapore is socio-political. Because the nation is small and relies only on human resources for its progress and prosperity, it is to the advantage of the nation that the gifted are helped and nurtured for “responsible leadership and service to country and society” (Ministry of Education, 2016b, para. 6). In Singapore, the goals of the GEP are as follows:

- intellectual depth and higher-level thinking
- productive creativity
- attitudes for self-directed lifelong learning
- aspirations for individual excellence and fulfillment
- a strong social conscience and commitment to serve society and nation
- moral values and qualities for responsible leadership. (Ministry of Education, 2016b, para. 6)

Given Singapore’s context, it is particularly imperative that the nation’s most able, best and brightest, who will provide leadership in various domains, have the disposition to serve the country and society for its betterment. Hence, the goal of the GEP is to equip pupils with the intellectual tools and attitudes to cope with the challenges of a fast-changing society in which they are likely to assume leadership roles. It also seeks to develop their values and abilities so that they can be at the forefront for the betterment of society (Quek, 1997).

2.2.3 Current Education System in Singapore

Singapore has a strong education system that aims to help its “students to discover their own talents, to make the best of these talents and realise their full potential, and to develop a passion for learning that lasts through life” (Ministry of Education, 2016a, para. 1). It is hoped that a person who has been part of the Singapore education system will be confident, a self-directed learner, an active contributor and a concerned citizen. The person will also have a good sense of self-awareness, a sound moral compass, and the required skills and knowledge to take on the challenges of the future. Therefore, the outcomes of education do not focus on just developing the academic potential of the students, but also place a large emphasis on developing the skills, character and values that enable students to continue to do well and take the country forward in the future.

In recent years, changes have been made to the education system to make it more flexible and diverse, to meet students' different interest and styles of learning, and to promote a diversity of talents among them. Students now have a wider choice of what and how they want to learn. A broad-based education system is also provided to ensure holistic development of the person to deal with the ambiguities for the future (Ministry of Education, 2016a).

It is compulsory for a Singaporean child to attend primary school. The pre-school years, however, are not compulsory but many parents enrol their children in pre-schools just to ensure that the child is ready for primary education. So the pre-school and primary education for a typical child in Singapore is as follows:

- Pre-school for children between the ages of 3 to 5 years
- Kindergarten for children between the ages 5 to 6 years
- Lower primary 1 to 3 (Grade 1 to 3) for children between the ages 7 to 9 years
- Upper primary 4 to 6 (Grade 4 to 6) for children between the ages 10 to 12 years.

At the secondary-school level, three courses are offered. Based on the child's Primary School Leaving Examination (PSLE) performance in Primary 6 (Grade 6), he/she will be placed in the Express Course (including the Integrated Programme in selected schools), the Normal (Academic) Course or Normal (Technical) Course. Though the child might start with a particular secondary course based on his/her current ability, learning pace and style, there are opportunities for a lateral transfer mid-stream to a more-suitable course that brings out his/her potential.

From 2004 onwards, the Integrated Programme (IP) was introduced in a few high-ranking public and independent secondary schools. It is a six-year programme that provides secondary students who are academically bright with a seamless education for advancing into pre-university institutions without taking the GCE ‘O’ level examination. The students in these programmes have more time and flexibility for engaging in broader learning experiences during their secondary and pre-university years. At the end of the sixth year, the students take the GCE ‘A’ level examination or the International Baccalaureate (IB).

The secondary school that was selected for my study is a specialised independent school and one of the highest ranking girls’ schools identified by the Ministry of Education in 2004 for offering its own IP. The aim is to use the time saved, which would have been otherwise used in preparing for the GCE ‘O’ levels, to stretch its pupils and provide a more holistic curriculum in both academic and non-academic areas. The school conducts its own school-based assessments to monitor its pupils’ progress. The students of this school are admitted based on their high PSLE scores and Direct Admission Exercise conducted by the school. The students of the school are among the top 1% to 3% of their cohort in terms of their performance in PSLE. Thirty percent of the students admitted are also from the Gifted Education Programme in their primary schools and, because the students are high-ability learners, the school adopts the Integrated Curriculum Model for the gifted (Van Tassel-Baska, 1986).

Although there is plenty of research literature and biographical and anecdotal accounts about gifted learners, there have been few studies of the experiences of gifted female students in science learning environments and even fewer of the attitudes of gifted students in science classrooms. This justifies the need for my study in this area.

2.2.4 Science Curriculum for Gifted Students in Singapore

Because the definition of giftedness over the centuries has varied with the different values of the culture, the programming to develop gifted students’ potential is also varied. Based on the diverse interpretations of gifted and talented, school leaders identify processes and programming practices. In 1988, the U.S. Congress provided a definition of gifted and talented that reads:

> The term ‘gifted and talented’, means children and youth who give evidence of high performance capability in areas such as intellectual, creative, artistic, or leadership capacity or in specific academic fields, and who require services or activities not ordinarily provided by the school in order to fully develop those capabilities. (Davis & Rimm, 2004, p. 19)

Most educational institutions focus on developing intellectually-gifted students. Van Tassel-Baska (2003) highlighted that the overriding trait of the intellectually-gifted is that they are developmentally advanced in language and thought. Consequently, she describes precocity, intensity and complexity as the three characteristics relevant to curriculum planning for the gifted and talented. Essentially, the definition of giftedness adopted by an educational institution largely determines the procedures used in identification of the gifted, the curriculum and programming, teacher training and administrative support.

Science is a discipline that naturally promotes the curiosity and intellectual spirit of gifted students and has been the fundamental area of interest for gifted children since their early years. However, this early interest in science is rarely matched with an appropriate curriculum within the school context (Van Tassel-Baska & Stambaugh, 2006). The National Commission on Excellence in Education Report (1983) reported that, during the past 15 years, students have not been achieving well in science, with problems including poor take-up rates of advanced courses which are frequently not being offered in many secondary schools (Bybee, 1994; National Science Board Commission on Precollege Education in Mathematics, 1983) and “girls and minority students…dropping out of the science track as early as possible” (Hilton, Hsia, Solorzano, & Benton, 1989, as cited in Van Tassel-Baska, Bass, Reis, Poland, & Avery, 1998, p. 201). Also science was taught through the use of texts that emphasised reading and guided experiments rather than active learning (Lockwood, 1992a, 1992b). To improve the quality of teaching and learning of science, the American Association for the Advancement of Science's Project 2061 published benchmarks of science literacy goals and, more recently, the National Research Council also published a set of national education science standards since 1990s (Van Tassel-Baska & Stambaugh, 2006).

The Javits programme, a project funded by the U.S. Department of Education, addressed the issue of world-class standards in science for developing and evaluating "curricula appropriate for high-ability learners. The National Curriculum Project for High Ability Learners at the College of William and Mary is one model for interpreting world class standards for K–8 students" (Van Tassel-Baska et al., 1998, p. 201). It was noted that there was close alignment between the new national science standards and the benchmarks of scientific literacy to the William and Mary curriculum.

The Ministry of Education of Singapore designs the science syllabus which extends from the Primary to the Pre-University Level. The syllabus at the lower levels is a bridge and foundation for the pursuit of scientific studies at upper levels. This syllabus is based on a Science Curriculum Framework that aims to provide a balance between the acquisition of science knowledge, skills and attitudes. In addition, as and when the topics lend themselves, the technological applications, social implications and the value aspects of science are also considered (Ministry of Education, 2016c). The science syllabus for gifted students is made more advanced to match their intellectual abilities. Though the same topics are taught, they are differentiated to include more depth and breadth in content. As a result, assessments for the gifted included more higher-order thinking questions compared to those for mainstream pupils.

In the science classroom, most students are inquirers who are curious and want to explore the things around them and hence the science curriculum seeks to fuel this spirit of curiosity. The end goal is that students enjoy science and value science as an important tool in helping them to explore their natural and physical world. The teacher is the leader, facilitator and role model of the inquiry process in the science classroom. Teachers of science impart the excitement and value of science to their students by creating a learning environment that encourages and challenges students to develop their sense of inquiry (Ministry of Education, 2016c).

Science teachers are strongly encouraged to exercise professional judgement to develop a science curriculum and schemes of work that enhance the learning of science. They incorporate ideas and materials from various sources based on the interests and abilities of the students and employ a variety of teaching and learning approaches for which the student is an inquirer (Ministry of Education, 2016c).

In Singapore schools, efforts are made to break away from the traditional approach to conceptual teaching by incorporating more hands-on activities and science investigations. The current digital age has also made computer technology an accessible tool in the classroom for improving science education in the classroom. Based on the principles of the Integrated Curriculum Model (Van Tassel-Baska, 1986) that were developed for high-ability learners, the key elements of the classroom include accelerated content knowledge organised around main concepts, higher-order critical and creative thinking processes, curriculum differentiation and interdisciplinarity.

Gifted students possess self-directed learning skills which apparently increase with age. This skill seems to correlate with the students' ability to think creatively (Torrance & Mourad, 1978). It is critical for teachers to create a classroom climate that encourages inquiry and independence as the gifted learn optimally in a student-centred environment. Self-directed learning allows increased student involvement and motivates them to learn (Treffinger, 1975). Collaboration is another important element in a gifted classroom as it promotes working with peers. It develops mutual scaffolding, shared cognition and critical thinking as students engage as teams to solve challenging and complex learning tasks or problems (Diezmann & Watters, 2001).

Continual formative assessments are useful in informing students of their progress in learning. It is an instructional tool that can also be used in differentiating instruction for gifted students because they have diverse needs (Callahan, 2012). With the introduction of technology, such as the use of laptop computers, into the education scene, it is hoped that the digital literacy of the students will improve together with their confidence in using the computers.

The curriculum programme in the school where my study took place specifically caters for intellectually-bright girls who are among the highest 3% of their cohort in the Primary School Leaving Examination (PSLE). It provides a holistic and challenging education that is broad-based in an attempt to develop thinking skills and an appreciation for lifelong learning. The curriculum emphasises the cultivation of life skills such as resilience, teamwork, problem-solving and decision-making. In order to provide a stimulating classroom and to stretch the minds of the girls in the classroom, the school trains its teachers to deliver a science curriculum with the following learning experiences:

- Higher-order thinking
- Self-directed learning
- Collaboration
- Curriculum differentiation
- Digital literacy
- Formative assessment.

Therefore, my study focused on the learning environment of the gifted in technology-based and regular science classrooms and assessed whether some of the school's curriculum objectives were being met.

My study also focused on the attitudes of the gifted girls in the two types of classrooms and the associations between students' perceptions of their learning environments and their attitudes. Although there is no empirical evidence that female students drop out of the science track in Singapore schools, anecdotal observations suggest that this is still an area of concern. Caleon and Subramaniam (2009) reported that boys have more positive attitudes in science than girls but this difference is less among gifted pupils. Another report on Singapore students indicated that girls have less positive beliefs in their abilities in science than boys (Martin, Mullis, Gonzalez, Gregory, Smith, Chrostowski, Garden & O'Connor, 2000).

Therefore, a purpose of this study was also to assess the extent to which female gifted students feel confident in using computers, perceive science as relevant, believe in their own ability and are motivated to study science.

2.3 History of the Field of Learning Environments

Studies in educational environments stem from early contributions by human psychologists, Kurt Lewin, Henry Murray, and their advocates. Lewin (1936) theorised that $B = f(P, E)$, where Behaviour (B) is a function (f) of the Person (P) and his/her Environment (E). Murray (1938) developed Lewin's theory further to include the idea of personal needs of an individual and the environmental press. This needs–press theory then resulted in the development of various measures for personality studies. Though Lewin's theory and Murray's needs–press model was known in the 1930s, for many decades, research on the person and the environment remained as two separate areas in educational psychology (Fraser & Fisher, 1983b). A technique for the measurement of socio-emotional climate in the classrooms was first developed by Withall (1949) to classify and observe elements of interactions in the classroom using trained observers.

Research on the person–environment fit as a key determinant of students' classroom functioning and achievement only began in the 1970s, many decades later, after Hunt's (1975) provocative review that re-identified researchers' reluctance to include both the person and the environment within the same studies (Fraser & Fisher, 1983b). Based on Murray's ideas, Stern (1970) proposed a theory that the complementary combination of personal needs and environmental press enhances student outcomes (Fraser & Fisher, 1983b).

Murray also contributed the concepts of *alpha press* and *beta press*, which were further developed by Stern et al. (1956) and to distinguish between private beta press (unique view of an individual in the environment) and consensual beta press (collective view of a group in the environment). There can be differences between private and consensual beta press and both could also differ from alpha press (the environment observed by a trained nonparticipant observer).

Getzels and Thelen (1960) were the first to propose a framework for analysing the classroom as a unique social system. A strong emphasis on inter-relationships and communications among all members of the classroom community was recommended by Doyle (1979) when assessing classroom environments. Fraser (1998b) defines learning environment as the "social, physical, psychological and pedagogical contexts in which learning occurs and which affects student achievement and attitudes" (p. 1).

Two highly-influential independent researchers, Herbert Walberg and Rudolf Moos, stimulated further studies on learning environments. Walberg designed the Learning Environment Inventory (LEI) to assess Harvard Project Physics, a curriculum development project in the USA (Walberg & Anderson, 1968). Moos (1979) first designed social climate scales to be administered in psychiatric hospitals and correctional institutions, and this eventually guided the design of the Classroom Environment Scale (CES) (Moos, 1979; Moos & Trickett, 1987).

Since the pioneering work of Walberg and Moos, major research programmes have been conducted on classroom environment, including the conceptualisation and development of other learning environment instruments (Fraser, 1986, 1994, 1998a, 2012, 2014; Goh & Khine, 2002). In Netherlands, Wubbels and his colleagues used the Questionnaire on Teacher Interaction (QTI) to study teacher–student interaction in the classroom (Fraser & Walberg, 2005; Wubbels & Brekelmans, 1998; Wubbels & Levy, 1993). Later, similar research was carried out in other countries (Goh & Fraser, 1998; Henderson et al., 2000; Kim et al., 2000; Quek et al., 2005; Scott & Fisher, 2004). The Individualised Classroom

Environment Questionnaire (ICEQ, Fraser, 1990; Fraser & Butts, 1982) was used to study student-centred classroom environments in Australia.

Walberg and Anderson (1972) found that students' perceptions of their classroom environment can be easily obtained with the use of learning environment scales administered during classroom time. Moreover, students' perceptions tend to be more accurate and advantageous because a larger sample is possible and subtle aspects of the learning environment could be missed or regarded as trivial by an observer (Fraser, 1991).

2.4 Range of Learning Environment Questionnaires

Many instruments have been designed in the last 40 years for use at the elementary to higher-education levels by researchers to assess classroom environments for different research objectives. Commonly-used instruments, including four historically-significant ones, are shown on Table 2.1. The name of each instrument, the grade level for which it is suitable and the number of items in each scale are also included in the table. Each of the scales in the instruments is also classified based on Moos's (1974) three basic types of dimensions: "Relationship; Personal Development; and System Maintenance and System Change. Relationship Dimensions identify the nature and intensity of personal relationships within the environment and assess the extent to which people are involved in the environment and assess the extent to which people are involved in the environment and support and help each other. Personal Development Dimensions assess basic directions along which personal growth and self-enhancement tend to occur. System Maintenance and System Change Dimensions involve the extent to which the environment is orderly, clear in expectations, maintains control and is responsive to change" (Walker & Fraser, 2005, p. 296).

The next few sections provide a review of the literature on the Learning Environment Inventory (LEI), Classroom Environment Scale (CES), Individualised Classroom Environment Questionnaire (ICEQ), and College and University Classroom Environment Inventory (CUCEI), My Class Inventory

(MCI), Questionnaire on Teacher Interaction (QTI), Science Laboratory Environment Inventory (SLEI), Constructivist Learning Environment Survey (CLES), What Is Happening In this Class? (WIHIC) questionnaire, Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI), Constructivist-Oriented Learning Environment Survey (COLES) and other classroom environment questionnaires. Because scales from the TROFLEI and COLES were used in my study, they are discussed in more depth.

2.4.1 Learning Environment Inventory (LEI)

The earliest version of the Learning Environment Inventory (LEI) was designed by Herbert Walberg in the late 1960s to assess and study the Harvard Project Physics, a curriculum development project in USA (Walberg & Anderson, 1968). The final version contains 15 scales with seven items per scale. The statements describe the dynamism within classrooms and respondents are given four alternatives, Strongly Disagree, Disagree, Agree and Strongly Disagree, to express their degree of agreement and disagreement. To avoid response bias, the scoring direction for some items is reversed. The LEI was used worldwide in over 300 research studies (Ellett & Walberg, 1979) and is suitable for secondary classrooms.

2.4.2 Classroom Environment Scale (CES)

Moos and Trickett (1987) developed the Classroom Environment Scale (CES) which originated from social climate scales administered in psychiatric hospitals and correctional institutions (Moos, 1974). The final version of the CES comprises nine scales with ten items of True–False response format and it has been used in secondary classrooms (Moos & Trickett, 1974; Trickett & Moos, 1973). Fisher and Fraser (1983b) validated the CES in Australia and demonstrated associations between CES scores and student outcomes. The final published version of this instrument includes “a test manual, a questionnaire, an answer sheet and a transparent hand-scoring key” (Fraser, 2012, p. 1198).

Table 2.1: Overview of the Scales Contained in Commonly-Used Classroom Environment Instruments

Instrument	Level	Items Per Scale	Scales Classified Based on Moos's 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	Task orientation Competition	Order and organisation Rule clarity Teacher control Innovation
Individualised Classroom Environment Questionnaire (ICEQ)	Secondary	10	Affliction Teacher support 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 Competiveness	
Questionnaire on Teacher Interaction (QTI)	Secondary/ Primary	8–10	Leadership Helpful/Friendly Understanding Student responsibility and freedom Uncertain Dissatisfied Admonishing 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 the Classroom? (WIHIC)	Secondary	8	Student cohesiveness Teacher support Involvement	Investigation Task orientation Cooperation	Equity
Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI)	Secondary	10	Student cohesiveness Teacher support Involvement Young adult ethos	Investigation Task orientation Cooperation	Equity Differentiation Computer Usage
Constructivist-Orientated Learning Environment Survey (COLES)	Secondary	11	Student cohesiveness Teacher support Involvement Young adult ethos Personal relevance	Task orientation Cooperation	Equity Differentiation Formative assessment Assessment criteria

Based on Fraser (2014)

2.4.3 Individualised Classroom Environment Questionnaire (ICEQ)

The Individualised Classroom Environment Questionnaire (ICEQ), designed by Rentoul and Fraser (1979), was based on studies on individualized classrooms that cater to open and inquiry-based education, numerous interviews with secondary-school teachers and students and feedback on preliminary versions from experts, teachers and junior high-school students (Rentoul & Fraser, 1979). This questionnaire assesses dimensions that differentiate individualised classrooms from conventional ones. The final published version contains five scales with 10 items in each scale (Fraser 1990; Fraser & Butts, 1982). There is a five-point frequency response format (Almost Never, Seldom, Sometimes, Often and Very Often) for each item. For many items, there is a reversal in the scoring direction. The printed version is copyrighted to allow users to make as many copies as needed of the response sheets and questionnaires.

2.4.4 College and University Classroom Environment Inventory (CUCEI)

The College and University Classroom Environment Inventory (CUCEI) was designed for studying the learning environments in higher-education classrooms (Fraser & Treagust, 1986). It was observed by Fraser, Treagust, Williamson and Tobin (1987) that not enough research has been conducted at higher-education levels relative to numerous studies of primary and secondary classroom environments.

The CUCEI was developed to evaluate students' perceptions in small classes with a membership of around 30 students (Fraser & Treagust, 1986). The final version of the instrument comprises seven scales and each scale has seven items. Respondents are given four alternatives (Strongly Agree, Agree, Disagree and Strongly Disagree) to express their degree of agreement and disagreement. For almost half of the items, the scoring direction is reversed.

In New Zealand, Logan, Crump and Rennie (2006) refined the CUCEI and administered in two studies in secondary and tertiary computing classrooms. The validity and reliability of the CUCEI was less-than-satisfactory across the two studies. Inappropriate item statements, the length of survey, the response format and the negatively-worded item statements were cited as some possible causes for the unsatisfactory statistical performance of the CUCEI.

A modified Arabic version of the CUCEI was used in college-level mathematics classes in the United Arab Emirates (UAE) to investigate the effectiveness of a variety of activity-based teaching strategies in terms of the nature of the classroom learning environment and students' satisfaction. This research is significant because it was one of the first studies of learning environments in the UAE involving adult male students, and because a modified and translated version of the CUCEI was validated for educators and researchers to use (Hasan & Fraser, 2015).

2.4.5 My Class Inventory (MCI)

The My Class Inventory (MCI) is a simplified version of LEI for use among primary-school children between 8 to 12 years (Fraser, Anderson, & Walberg, 1982). The original version of MCI was further simplified by Fisher and Fraser (1981). To make it more readable and reduce fatigue when used with younger children, the instrument was modified into a short 25-item version (Fraser & O'Brien, 1985).

MCI comprises the following five of the LEI's 15 scales: Cohesiveness, Friction, Satisfaction, Difficulty and Competitiveness. The use of simple words makes this instrument suitable for junior high-school students as well. Also, the four-point response format in the LEI was changed to a two-point response (Yes–No) in the MCI. The students are required to respond on the questionnaire rather than a separate sheet to reduce errors in recording responses. The final version of the MCI is now available in a long form (38 items) or short form (25 items). In Singapore, Goh and Fraser (1998) adapted the MCI and administered it in a study in primary mathematics classes. This version included a Task Orientation scale and has a three-point response format (Seldom, Sometimes and Most of the Time).

Majeed, Fraser and Aldridge (2002) used an English-language version of the MCI in a study in Brunei Darussalam involving 1565 lower-secondary mathematics students in 81 classes in 15 government schools. Besides establishing "a satisfactory factor structure for a refined three-scale version of the MCI assessing cohesiveness, difficulty and competition" (Majeed et al., 2002, p. 203), this study revealed gender differences in students' perceptions of their learning environment and association between students' satisfaction and the type of learning environment. In another study undertaken in Florida, the MCI, attitude scales and qualitative methods were used to assess a K–5 mathematics programme that integrates children's literature. The sample in the study contained 120 grade 5 mathematics students and the study revealed that the introduction of the programme had a favourable effect because there was agreement between students' actual and preferred classroom environment (Mink & Fraser, 2005). In Washington, a study by Sink and Spencer (2005) with an extensive sample of 2835 students reported that a revised 18-item version of the MCI was valid and reliable instrument to be used by elementary-school counsellors. The MCI was also used to evaluate science kits among 588 grade 3–5 students in Texas. The study attested to the validity of the MCI and that the use of science kits was associated with positive learning environments (Houston, Fraser, & Ledbetter, 2008).

2.4.6 Questionnaire on Teacher Interaction (QTI)

The Questionnaire on Teacher Interaction (QTI) was designed to assess the type of teacher–student relationships. It was a product of pioneering and programmatic research undertaken in the Netherlands at the senior high-school level (Creton, Hermans, & Wubbels, 1990; Wubbels & Brekelmans, 1998, 2012; Wubbels & Levy, 1993). Now, there is a shorter version (Goh & Fraser, 1996) and a modified form which measures teachers' or principals' perceptions of a principal's interaction with teachers (Fisher & Cresswell, 1998). In Brunei Darussalam, Scott and Fisher (2004) validated a Malay version of the QTI with 3104 students in 136 elementary school classrooms. An English version was validated in Singapore in a study with a sample of 497 gifted and non-gifted students in secondary chemistry classrooms, and stream and gender differences in QTI scores were reported (Quek et al., 2005). Translated versions of QTI have been validated in studies undertaken in Korea (Kim et al., 2000; Lee, Fraser, & Fisher, 2003) and Indonesia (Fraser, Aldridge, & Soerjaningsih, 2010).

2.4.7 Science Laboratory Environment Inventory (SLEI)

The Science Laboratory Environment Inventory (SLEI) was developed to assess the significant and unique setting of the laboratory class in learning science at the senior-high and higher-education levels (Fraser, Giddings, & McRobbie, 1995; Fraser & McRobbie, 1995; Fraser, McRobbie, & Giddings, 1993). This 35-item instrument has five scales with seven items in each scale. The respondents are given five frequency alternatives, Almost Never, Seldom, Sometimes, Often and Very Often. The SLEI was validated in a large study simultaneously in six countries, USA, Canada, England, Israel, Australia, and Nigeria, with a sample size of 5447 students in 269 classes. Cross-validations were also undertaken in studies in Australia with 1594 students (Fraser & McRobbie, 1995) and 489 biology students (Fisher, Henderson, & Fraser, 1997).

In Singapore, the SLEI was cross-validated among 1595 Grade 10 chemistry students from 56 classes in 28 schools by Wong and Fraser (1996). Quek et al. (2005) further cross-validated the SLEI among a sample of 497 gifted and non-gifted chemistry students. These studies revealed associations between the learning environment and students' affective outcomes. Fraser and Lee (2009) translated the SLEI into the Korean language and used it among a sample of 439 high-school students to investigate differences between the classroom environments of three streams (science-independent, science-oriented and humanities). "Students in the science-independent stream generally perceived their science laboratory classroom environment more favourably than did students in either the humanities or science-oriented stream" (Fraser & Lee, 2009, p. 67). In USA, Lightburn and Fraser (2007) used the SLEI with a sample of 761 high-school biology students in 25 classes in the United States to assess the success of using anthropometry activities. This study attested to SLEI's validity and supported the effectiveness of anthropometric activities with regards to both learning environment and student attitudes.

2.4.8 Constructivist Learning Environment Survey (CLES)

The Constructivist Learning Environment Survey (CLES) was developed by researchers and teachers who were interested in the extent to which classroom practices are aligned to constructivist epistemology (Taylor, Fraser, & Fisher, 1997). Constructivist learning is a cognitive process in which students make meaning by building on their prior knowledge. This research helped teachers to reflect on their pedagogical assumptions and modify their teaching practices. The CLES was validated by Taylor et al. (1997) using a sample of 494 students in Grades 8 and 9 from 41 classes within 13 schools in Australia and 1,600 students in Grades 9–12 in Texas. The CLES contains five seven-item scales pertinent to the principles of constructivism: Personal Relevance, Uncertainty, Critical Voice, Shared Control and Student Negotiation. Respondents are given five alternatives for each item, Almost Never, Seldom, Sometimes, Often and Almost Always.

In another study undertaken by Nix, Fraser, and Ledbetter (2005) in North Texas, the CLES was used to assess the Integrated Science Learning Environment (ISLE), an innovative science teacher professional development programme. In this study, the CES was found to be valid with a sample of 1,079 students in 59 science classes. Nix et al. (2005) also reported that pupils of teachers who had completed the ISLE programme perceived their learning environment more positively than students of teachers who did not enrol in the development programme.

Johnson and McClure (2004) designed a more-economical version of the CLES which contained 20 items in the original five scales. The instrument had strong validity and reliability when used with upper-elementary, middle-school and high-school students and teachers. This short instrument was used again in Texas, in a further study by Nix and Fraser (2011), to assess the introduction of the ISLE model.

In a cross-national study by Aldridge, Fraser, Taylor, and Chen (2000) in middle-school science classroom learning environments in Australia and Taiwan, the CLES was reported to have sound validity and reliability and the ability to differentiate between classrooms when an "English version of the CLES was used with a sample of 1,081 students in 50 classes in Australia while a Mandarin translation was administered to 1,879 students in 50 classes in Taiwan". Also "Australian classes were perceived as being more constructivist than Taiwanese classes" (Fraser, 2012, pp. 1202-1203).

The CLES was modified and translated into Spanish and both English and Spanish versions were used in a study by Peiro and Fraser (2009) among 739 students in Grades K–3 in Miami, Florida. The study attested to the sound validity for both the English and Spanish forms when used with young students. In this research, positive associations were found between students' attitudes and the classroom learning environment.

In South Africa, the CLES was used with a sample of 1,864 mathematics students in Grades 4, 5, and 6 from 43 classes (Aldridge, Fraser, & Sebela, 2004). The CLES was cross-validated and exhibited sound factor structure, internal consistency reliability and ability to differentiate between classrooms. The main objective of this study was to enable South African teachers to improve constructivist teaching in the classrooms.

The CLES was translated into the Korean language and used with a sample of 1,083 Grade 10 and 11 students in 24 science classes from 12 different schools in Korea (Kim, Fisher, & Fraser, 1999). The CLES was cross-validated and found to have sound validity (factor structure, reliability and ability to differentiate between classrooms) in Korea. This study also showed statistically significant relationships between classroom environment and student attitudes and suggested also that the Grade 10 students exposed to a new general science curriculum perceived a more constructivist learning environment than did Grade 11 students who had not been exposed to this curriculum reform (Kim et al., 1999).

Koh and Fraser (2014) used the CLES in Singapore to evaluate the effectiveness of a pedagogical model known as the Mixed Mode Delivery (MMD) model. Five scales, namely, personal relevance, uncertainty, critical voice, shared control and negotiation were used to compare the actual and preferred learning environment of 2216 secondary school students taught by the preservice teachers in an MMD group and 991 students in a control group. Based on the students’ perceptions of their classroom environments for all five CLES scales, the study supported the positive impact of using MMD.

2.4.9 What Is Happening In this Class? (WIHIC)

One of the most commonly-used questionnaire is the What Is Happening In this Class? (WIHIC). It combines scales from a wide range of existing questionnaires and adds scales that address current educational issues. It has been translated into many languages and used in many studies worldwide. Developed by Fraser et al. (1996), “the WIHIC has a Class form (which assesses a student’s perceptions of the class as a whole) and a Personal form (which assesses a student’s personal perceptions of his or her role in a classroom)” (Fraser, 2012, p. 1205). The Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI), the instrument from which I chose some of the scales to use in my study, is based on the WIHIC. The WIHIC is parsimonious in that it brings into one questionnaire numerous critical scales from a range of existing questionnaires as well as scales which relate to current educational emphases such as constructivism and equity.

Fraser et al. (1996) first developed a 90-item nine-scale version of the WIHIC which was refined after data from 355 junior high-school science students were analysed. Students were also interviewed about their opinions of the learning environment, the wording and significance of each item and their responses to the questionnaire. Based on the analysis, only 54 items were retained and expanded to an 80-item version to be field tested later with junior high-school science classes in Australia and Taiwan. This led to the final form of the WIHIC containing the seven eight-item scales described by Aldridge, Fraser and Huang (1999). The English version of the WIHIC was administered to 1,081 students in 50 classes in Australia, while a Mandarin version was administered to 1,879 students in 50 classes in Taiwan (Aldridge et al., 1999).

Dorman (2003) confirmed the WIHIC's wide international applicability by conducting an extensive validation using a cross-national sample of 3980 high-school students in Australia, the UK and Canada. In another study in Australia, Dorman (2008) administered the actual and preferred forms of the WIHIC to 978 secondary-school students. This study supported the sound psychometric properties of the WIHIC.

Table 2.2 provides a summary of studies undertaken in different countries which reported the sound factorial validity and internal reliability of the WIHIC. For each of the 26 studies listed in the table, the language, sample size, grade level and number of classes involved are shown. The last two columns report whether each study involved associations between classroom environment and student outcomes and identify the special contributions made by each to the field of learning environment.

The first four studies in Table 2.2 are cross-national research undertaken in Australia and Taiwan (Aldridge & Fraser, 2000), in Australia, the UK and Canada (Dorman, 2003), in Australia and Indonesia (Fraser, Aldridge, & Adolphe, 2010) and in Australia and Canada (Zandvliet & Fraser, 2004, 2005). The WIHIC was used in two languages, English and Mandarin, in the study by Aldridge and Fraser (2000) and in English and Bahasa in the study undertaken by Fraser et al. (2010). The next six studies shown in Table 2.2 were undertaken in Singapore (Chionh & Fraser, 2009; Khoo & Fraser, 2008; Peer & Fraser, 2015), India (Koul & Fisher, 2005), Australia (Dorman, 2008) and South Africa

Table 2.2: Summary of Studies which Reported Sound Validity and Reliability for the WIHIC

Reference(s)	Country(ries)	Language(s)	Sample(s)	Associations with Environment for:	Unique Contributions
Aldridge et al. (1999); Aldridge & Fraser (2000)	Australia Taiwan	English Mandarin	1081 (Australia) & 1879 (Taiwan) junior high science students in 50 classes	Enjoyment	Mandarin translation; Combined quantitative and qualitative methods
Dorman (2003)	Australia UK Canada	English	3980 high school students	NA	Confirmatory factor analysis substantiated invariant structure across countries, grade levels & sexes.
Fraser et al. (2010)	Australia Indonesia	English Bahasa	567 students (Australia) and 594 students (Indonesia) in 18 secondary science classes	Several attitude scales	Differences were found between countries and sexes.
Zandvliet & Fraser (2004, 2005)	Australia Canada	English	1404 students in 81 networked classes	Satisfaction	Involved both physical (ergonomic) and psychosocial environments.
Chionh & Fraser (2009)	Singapore	English	2310 grade 10 geography & mathematics students	Achievement Attitudes Self-esteem	Differences between geography & mathematics classroom environments were smaller than between actual & preferred environments.
Khoo & Fraser (2008)	Singapore	English	250 working adults attending computer education courses	Satisfaction	Adult population Males perceived more trainer support & involvement but less equity.
Peer & Fraser (2015)	Singapore	English	1081 primary-school students in 55 classes	Attitudes	Statistically significant difference were revealed for sex, grade-level, stream, stream–by–sex interaction and grade–by–stream interaction

Table 2.2: Summary of Studies which Reported Sound Validity and Reliability for the WIHIC (cont'd)

Reference(s)	Country(ries)	Language(s)	Sample(s)	Associations with Environment for:	Unique Contributions
Koul & Fisher (2005)	India	English	1021 science students in 31 classes	NA	Differences in classroom environment according to cultural background
Dorman (2008)	Australia	English	978 secondary school students	NA	multi-trait–multi-method modelling validated actual and preferred forms.
Aldridge et al. (2009)	South Africa	English	1077 grade 4–7 students	NA	Preservice teachers undertaking a distance-education programme used environment assessments to improve teaching practices.
Kim et al. (2000)	Korea	Korean	543 grade 8 science students in 12 schools	Attitudes	Korean translation Sex differences in WIHIC scores
Wahyudi & Treagust (2004)	Indonesia	Indonesian	1400 lower-secondary science students in 16 schools	NA	Indonesian translation Urban students perceived greater cooperation & less teacher support than suburban students.
MacLeod & Fraser (2010)	UAE	Arabic	763 college students in 82 classes	NA	Arabic translation Students preferred a more positive actual environment.
Afari et al. (2013)	UAE	Arabic	352 college students in 33 classes	Enjoyment Academic efficacy	Arabic translation Use of games promoted a positive classroom environment.
den Brok, Fisher, Rickards, & Bull (2006)	California, USA	English	665 middle-school science students in 11 schools	NA	Girls perceived the environment more favourably.

Table 2.2: Summary of Studies which Reported Sound Validity and Reliability for the WIHIC (cont'd)

Reference(s)	Country(ries)	Language(s)	Sample(s)	Associations with Environment for:	Unique Contributions
Martin-Dunlop & Fraser (2008)	California, USA	English	525 female university science students in 27 classes	Attitude	Very large increases in learning environment scores for an innovative course
Ogbuehi & Fraser (2007)	California, USA	English	661 middle-school mathematics students	Two attitude scales	Used 3 WIHIC & 3 CLES scales Innovative teaching strategies promoted task orientation.
Taylor & Fraser (2013)	California, USA	English	745 high-school mathematics students in 34 classes	Anxiety	Involved mathematics anxiety Females perceived the environment more favourably
Long & Fraser (2015)	Texas, USA	English	367 grade 8 science students	Attitudes	General science curriculum model more effective than specific model for Hispanic students in terms of Task Orientation
Wolf & Fraser (2008)	New York, USA	English	1434 middle-school science students in 71 classes	Attitudes Achievement	Inquiry-based laboratory activities promoted cohesiveness & were differentially effective for males and females.
Cohn & Fraser (2016)	New York, USA	English	1097 grade 7 and 8 students	Attitudes Achievement	Very large differences reported between users and non-users of SRS (Student Response Systems)
Oser & Fraser (2015)	New York, USA	English	322 grade 8 to 10 students in 12 classes	Attitudes Achievement	Virtual laboratories were more advantageous for males than females on several criteria

Table 2.2: Summary of Studies which Reported Sound Validity and Reliability for the WIHIC (cont'd)

Reference(s)	Country(ries)	Language(s)	Sample(s)	Associations with Environment for:	Unique Contributions
Pickett & Fraser (2009)	Florida, USA	English	573 grade 3–5 students	NA	Monitoring programme for beginning teachers was evaluated in terms of changes in learning environment in teachers' school classrooms.
Allen & Fraser (2007)	Florida, USA	English Spanish	120 parents and 520 grade 4 & 5 students	Attitudes Achievement	Involved both parents and students Actual–preferred differences were larger for parents than students.
Robinson & Fraser (2013)	Florida, USA	English Spanish	78 parents and 172 kindergarten science students	Attitudes Achievement	Kindergarten level Involved parents Spanish translation Relative to students, parents perceived a more favourable environment but preferred a less favourable environment.
Helding & Fraser (2013)	Florida, USA	English Spanish	924 students in 38 grade 8 & 10 science classes	Attitudes Achievement	Spanish translation Students of NBC teachers had more favourable classroom environment perceptions.

Adapted from Fraser (2012)

(Aldridge, Fraser, & Ntuli, 2009). In the next two studies, the WIHIC was translated into the Korean and Indonesian language, respectively, before use (Kim et al., 2000; Wahyudi & Treagust, 2004).

In the thirteenth and fourteenth studies, the WIHIC was translated into the Arabic language and used in the Arab Emirates (MacLeod & Fraser, 2010; Afari, Aldridge, Fraser, & Khine, 2013). The final twelve studies seen in Table 2.2 were undertaken in USA. The WIHIC was used in four studies in California (den Brok et al., 2006; Martin-Dunlop & Fraser, 2008; Ogbuehi & Fraser, 2007; Taylor & Fraser, 2013), three in New York (Cohn & Fraser, 2016; Oser & Fraser, 2015; Wolf & Fraser, 2008), one in Texas (Long & Fraser, 2015) and four in Florida (Allen & Fraser, 2007; Helding & Fraser, 2013; Pickett & Fraser, 2009; Robinson & Fraser, 2013). The last three studies (Allen & Fraser, 2007; Helding & Fraser, 2013; Robinson & Fraser, 2013) also provided the students with the option to choose between either an English or Spanish version of the WIHIC.

The last column in the table also includes some significant and unique findings for each study. For example, Kim et al. (2000) reported sex differences in the WIHIC scores. Afari et al. (2013) found that the use of mathematical games fostered desirable classroom environments and students' attitudes towards mathematics. Helding and Fraser (2013) reported that students of National Board Certified (NBC) teachers had more positive classroom environment perceptions than students of non-NBC teachers. Khoo and Fraser (2008) reported that working adult males perceived more trainer support and involvement than females, whereas females perceived more equity than males.

2.4.10 Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI)

There are two common approaches to outcomes-focused education: the traditional/transitional approach and the transformational approach. Traditional outcomes reflect curriculum-based objectives or subject-related content that students should learn and master, whereas transformational outcomes refer to exit outcomes that are cross-curricular and have long-term impact beyond the classroom. Some of these student outcomes which lead to more significant learning are those which are related to a person's life roles, such as being a self-directed learner, complex thinker and community contributor (Aldridge & Fraser, 2008). Most educational models in many countries focus on the transformational approach to outcomes-focused education in which the student outcomes, for example 21st Century skills in the global economy and workplace, are identified and then curriculum is planned, delivered and assessed with a focus on developing the desired outcomes.

The use of Information and Communication Technology (ICT) is becoming a common practice in schools for classroom instruction because it allows students to work individually at their own pace with the assistance of an oversupply of online educational resources. To help to assess the present-day classroom that infuses ICT into the curriculum and supports the school's increased focus on outcomes-based education, Aldridge and Fraser (2008) developed the TROFLEI in conjunction with a study of an innovative new post-secondary school which employed the use of ICT in its first year of operation to achieve student outcomes. The study monitored and evaluated the efficacy of the school's outcome-focused education using changes in students' perceptions of the learning environment over 4 years. The sample comprised 2317 Western Australian and Tasmanian students in grade 11 and 12 in 166 classrooms. The study established strong factorial validity and internal consistency reliability for both the actual and preferred forms of the TROFLEI. The actual form of the TROFLEI was also able to differentiate between the perceptions of students in different classrooms.

Aldridge et al. (2004) validated the TROFLEI using a multi-trait–multi-method model. They used a large sample of 1249 male and female high-school students in Western Australia and Tasmania in this validation. This study supported the validity of the actual and preferred forms of the TROFLEI. The questionnaire is an extension of the commonly-used learning environment instrument, the WIHIC, which provides an assessment of classrooms with a focus on technology and outcomes in secondary schools.

The TROFLEI incorporates all seven scales of the WIHIC, as well as three other classroom environment dimensions: Differentiation, Computer Usage and Young Adult Ethos. In other words, this instrument contains 10 scales with 8 items each. To identify the extent to which the teacher provides for individualism, a Differentiation scale was adapted from the Individualised Classroom Environment Questionnaire (ICEQ; Fraser, 1990). The extent and the variety of ways to which computers are used in the classroom is assessed using the Computer Usage scale. A Young Adult Ethos scale is included to assess opportunities provided by teachers for students' self-directed learning.

The 80 items in this instrument have a five-point frequency response scale (Almost Never, Seldom, Sometimes, Often and Almost Always). The items in the same scale are arranged together in blocks rather than in random or cyclic fashion because the latter can provide clues and cause confusion (Aldridge et al., 2000). The aggregate score for the eight items in a scale is calculated for each respondent. Also, the instrument can be administered economically because students record their perceptions of actual and preferred environments using adjacent response scales.

There are numerous studies reviewed in Section 2.4.9 and Table 2.2 attesting to the successful use of the WIHIC and its strong factorial validity and internal consistency. Though studies involving the use of the TROFLEI are not as numerous as for the WIHIC, there are several important studies that have supported the sound validity and reliability of the TROFLEI.

Dorman et al. (2006) used cluster analysis with the TROFLEI to identify and compare five homogenous types of classroom environments which were described as: "exemplary; safe and conservative; non-technological teacher-centred; contested technological; and contested non-technological" (Dorman et al., 2006, p. 906).

Dorman and Fraser (2009) studied associations between students' affective outcomes and their classroom environment perceptions using the TROFLEI. A factor analysis confirmed the ten-scale structure of the TROFLEI. Structural equation modeling revealed that improving classroom environment has the potential to improve student outcomes. Dorman and Fraser (2009) used the TROFLEI to reveal statistically-significant associations between classroom environment and student affective outcomes with 4407 Australian secondary-school students in Queensland and Western Australia. Similar results were obtained with and 4,146 high school students from Western Australia and Tasmania (Dorman & Fraser, 2009).

Koul, Fisher and Shaw (2011) carried out a study with 1027 high-school students in New Zealand using the actual and preferred forms of the TROFLEI to determine the effectiveness of a technology-supported classroom in achieving selected affective outcomes. Also girls perceived their technology-related learning environment more positively than boys.

Cakir (2011) investigated the validity and reliability of a Turkish version of the TROFLEI with 985 students from Grades 9–12. When Welch, Cakir, Peterson and Ray (2012) cross-validated the TROFLEI in Turkey and the USA, they established sound validity and reliability for the instrument. About 980 students attending grades 9–12 in Turkey and 130 students attending grades 9–12 in the USA participated in the study. Gupta and Fisher (2012) carried out the first study in India using a modified version of the TROFLEI to assess 705 students' perceptions of their learning environments in technology-supported science classrooms. In New Zealand, Koul et al. (2011) used the actual and preferred forms of the TROFLEI with 1027 high-school students from 30 classes to reveal sound validity and reliability. Students participating in the study preferred a better learning environment and female students generally perceived their technology-related learning environments more positively than males. Statistically-significant associations were also found between the scales of the TROLFLEI and three affective outcome scales. To meet the objectives of my research, I selected five scales from the TROFLEI to include in the learning environment questionnaire in Appendix A.

2.4.11 Constructivist-Orientated Learning Environment Survey (COLES)

The Constructivist-Orientated Learning Environment Survey (COLES) is designed to provide feedback to teachers wanting to improve their classroom environments through action research (Aldridge et al., 2012). This instrument contains mostly the scales from the WIHIC, but also includes scales associated to the assessment of student learning, which is missing in all the existing classroom environment questionnaires (Aldridge et al., 2012).

The COLES comprises the following six scales derived from the WIHIC: Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Cooperation and Equity; the WIHIC's Investigation scale was omitted. The scales of Differentiation and Young Adult found in the TROFLEI and the Personal Relevance in the CLES were also incorporated into the COLES. The COLES also includes two new scales related to assessment, namely, Formative Assessment and Assessment Criteria, making a total of 11 scales in this instrument.

Aldridge et al. (2012) reported sound factorial validity and internal consistency reliability for both actual and preferred versions of the COLES when administered to 2043 grade 11 and 12 students from 147 classes in nine schools in Western Australia. Teachers undertaking action research with the hope to improve the learning environments have found the COLES to be an effective instrument. My study incorporated the Formative Assessment scale from the COLES with five scales from the TROFLEI to create a learning environment instrument suitable for meeting the objectives of my research.

Bell and Aldridge (2014) validated the COLES with a large-scale sample of schools in Western Australia and investigated the effectiveness of using student perceptions for developing teacher expertise and improving classroom practice. The research programme started in 2008 with a small number of schools but, as more schools became interested, the number of schools, students and teachers increased in 2009 and 2010. Over the three-year period, 548 teachers, 684 classes, 10345 students and 29 schools were involved in the research. The results in this study supported that the COLES was a valid and reliable instrument for assessing students' perceptions of the classroom psychosocial environment.

2.4.12 Other Classroom Environment Questionnaires

In many studies undertaken in Australia and worldwide, researchers have designed other instruments or used a modified version of existing classroom environment questionnaires to suit their research purpose or research contexts. For example, Walker and Fraser (2005) developed a new online learning environments instrument called the Distance Education Learning Environments Survey (DELES) to assist researchers and instructors to study the unique social-psychosocial learning environment in post-secondary distance education. The instrument was validated with 680 distance learning students. The DELES has six scales, namely, Instructor Support, Student Interaction and Collaboration, Personal Relevance, Authentic Learning, Active Learning and Student Autonomy. An Enjoyment scale was added to this study to examine correlations between the learning environment and student affective outcomes.

Another distinctive study by Fisher and Waldrip (1997) explored associations between students' perceptions of their culturally-sensitive learning environment, their attitudes towards science, and their achievement of inquiry skills. The Cultural Learning Environment Questionnaire (CLEQ), a new questionnaire containing eight scales, namely, Gender Equity, Collaboration, Risk Involvement, Competition, Teacher Authority, Modelling, Congruence and Communication, was developed and validated to assess the culturally-sensitive environments of secondary school students.

Though the number of studies of classroom environment is voluminous, there have been few studies assessing school environment which could help teachers (Huang & Fraser, 2009) or school leaders to assess and improve their school environments. Rentoul and Fraser (1983) developed the School-Level Environment Questionnaire (SLEQ) to examine teachers' perceptions of psychosocial learning environment of primary or secondary schools using eight scales closely aligned to Moos's three categories of human environments, namely, Affiliation, Student Supportiveness, Professional Interest, Achievement Orientation, Formalisation, Centralisation, Innovativeness and Resource Adequacy. Results from this study suggest that the SLEQ is useful in research related to the impact of school-level environment on classroom environment and teachers' teaching behaviours.

2.5 Types of Learning Environment Research

Fraser (2012) identified the following 10 different types of research involving the use of classroom environment instruments:

- associations between student outcomes and the classroom environment,
- evaluation of educational innovations,
- teachers' practical attempts to improve their classroom and school environments,
- differences between student and teacher perceptions of actual and preferred environment,
- combining quantitative and qualitative methods,
- school psychology,
- links between educational environments,
- cross-national studies,
- transition between different levels of schooling, and
- typologies of classroom environments. (p. 1217)

For the purpose and context of my study, the first three types of past research are discussed in detail below.

2.5.1 Associations Between Student Outcomes and Environment

Fraser (1994) identified 40 past studies in science education of associations between students' cognitive and affective learning outcomes and classroom environment perceptions. These studies were undertaken using a variety of classroom environment instruments, cognitive and affective outcomes and samples in numerous countries and at various grade levels. In my study, one of the objectives was to explore associations between students' perceptions of their learning environment and student affective outcomes.

The SLEI was used to identify the associations between the classroom environment and students' cognitive and affective outcomes with a sample of approximately 80 senior high-school chemistry classes in Australia (Fraser and McRobbie, 1995; McRobbie and Fraser, 1993), 489 senior high-school biology students in Australia (Fisher et al., 1997) and 1,592 grade10 chemistry students in Singapore (Wong and Fraser, 1996).

Teh and Fraser (1995) found associations between classroom environment, achievement and attitudes employing an instrument, relevant for computer-assisted learning environments, called the Geography Classroom Environment Inventory (GCEI). The GCEI was used with a sample of 671 high-school geography students in 24 classes in Singapore.

Associations between student outcomes and perceived teacher–student interactions were studied using QTI with a sample of 489 senior high-school biology students in Australia (Fisher, Henderson & Fraser, 1995) and 1512 primary-school mathematics students in Singapore (Goh, Young, & Fraser, 1995). In a study undertaken in Singapore by Wong, Young and Fraser (1997) with 1592 grade 10 students in 56 chemistry classes, associations were found between three student attitudes and a modified version of the SLEI. In another study in Singapore, Goh et al. (1995) reported that scales of MCI were related to student achievement and attitudes for a sample of 1512 grade 5 mathematics students in 39 classes. Chionh and Fraser (2009) used the WIHIC among 2310 Grade 10 mathematics and geography students and found associations between the learning environment and student attitudes and achievement. For example, students in classrooms with higher levels of student cohesiveness had better examination scores, and students in classes with greater teacher support, task orientation and equity had more favourable self-esteem and attitudes.

Telli, den Brok and Cakiroglu (2010) translated the QTI into the Turkish language and studied associations between students' attitudes to science and teacher–student interpersonal behavior using an attitude questionnaire developed by Fraser (1981). A large sample of 7,484 students in Grades 9, 10 and 11 from 278 classes in 55 public schools in 13 major Turkish cities were involved in this study. It was found "that the influence was related with student enjoyment, while proximity was associated with attitudes towards inquiry" (Telli et al., 2010, p. 261).

In a study in Western Australia and Tasmania, Dorman and Fraser (2009) used the TROFLEI among 4,146 high-school students to investigate classroom environment, antecedent variables, and student affective outcomes such as attitude to the subject, attitude to computer use and academic efficacy. Improving classroom environment led to improved student outcomes. The "antecedents did not have any significant direct effect on outcomes; and academic efficacy mediated the effect of several classroom environment dimensions on attitude to subject and attitude to computer use" (Dorman & Fraser, 2009, p. 77).

Associations between classroom environment and student outcomes were reported in a study by Edward Haertel, Herbert Walberg and Geneva Haertel (1981). Their meta-analysis involved "734 correlations from 12 studies involving 823 classes, eight subject areas, 17,805 students and four nations. Learning post-test scores and regression-adjusted gains" (Fraser, 2012, p. 1219) were strongly correlated with cognitive and affective learning outcomes. "Learning outcomes and gains are positively associated with Cohesiveness, Satisfaction, Task

Difficulty, Formality, Goal Direction, Democracy, and the Material Environment and negatively associated with Friction, Cliqueness, Apathy, and Disorganisation" (Haertal et al., 1981, p. 27). Another 134 meta-analyses reported by Fraser, Walberg, Welch and Hattie (1987) attested to an association between educational environments and student outcomes. The analyses were based on 7,827 studies, 22,155 correlations and around 5–15 million students in kindergarten through to college. Further analyses by Walberg (1986), Fraser, Welch and Walberg (1986) and Walberg, Fraser and Welch (1986) concluded that classroom and school environments were strong predictors of both achievement and attitudes even when numerous other factors were held constant.

2.5.2 Evaluation of Educational Innovations

Fraser (2012) stated that "classroom environment instruments can be used as a source of process criteria in evaluating innovations in education" (p. 1220). This is relevant to my research which investigated the effectiveness of technology-based classrooms compared with regular classrooms in terms of students' learning environment perceptions. Five scales from the TROFLEI and one scale from the COLES were selected for inclusion in a learning environment questionnaire suitable for my research purposes and context (see Chapter 3, Section 3.6.1).

In Singapore, two studies used classroom environment scales as dependent variables in evaluations of computer-assisted learning (Teh & Fraser, 1994) and computer application courses for adults (Khoo & Fraser, 2008). Khoo and Fraser (2008) used an adapted version of the WIHIC among a sample of 250 working adults. "Students perceived their classroom environments positively" but "males perceived significantly more Involvement, whereas females perceived more Equity" (Khoo & Fraser, 2008, p. 67). Also in Singapore, Koh and Fraser (2014) used the CLES to evaluate the effectiveness of a pedagogical model known as the Mixed Mode Delivery (MMD) model. Based on the students' perceptions of their classroom environments, the study supported the positive impact of using MMD.

Maor and Fraser (1996) incorporated a classroom environment instrument within an evaluation of the use of a computerised database. The students perceived that there was more inquiry in the classes during the innovation. Nix et al. (2005), as mentioned in Section 2.4.8, used the CLES to assess “an innovative teacher development program (based on the Integrated Science Learning Environment, ISLE, model)” (Nix et al., 2005, p. 109). The ISLE was assessed in terms of the types of classroom learning environments fostered by teachers as perceived by their 445 students in 25 classes in Texas. The students provided their perceptions of the current class taught by the teacher who had been in ISLE programme and other classes at the same school taught by different teachers who had not been in the ISLE programme. The study revealed that “students whose teachers had attended the ISLE program…perceived higher levels of Personal Relevance and Uncertainty of Science” (Nix et al., 2005, p. 109) relative to the comparison classes.

Martin-Dunlop and Fraser (2008) used scales selected from the WIHIC and the SLEI to evaluate an innovative science course for elementary school teacher trainees in a university in California. The sample consisted of 525 females in 27 classes. The study reported large difference (of over 1.5 standard deviations) between students’ perceptions of the innovative course and their previous courses.

Lightburn and Fraser (2007) used the SLEI with a sample of 761 high-school biology students in 25 classes in Florida, United States, to assess the effectiveness of using anthropometry activities. The anthropometric group had higher scores on some SLEI and attitude scales relative to the comparison group.

In order to evaluate the effectiveness of an innovative new senior-high school in Western Australia in promoting outcomes-focused education, the TROFLEI was used. A sample of 1918 students was monitored over a four-year period. Statistically-significant changes of moderate magnitude (with effect sizes ranging from 0.20 to 0.38 standard deviations) for seven of the ten TROFLEI scales in students' perceptions of the classroom environment over the four years supported the efficacy of the school's educational programme (Aldridge & Fraser, 2008).

Pickett and Fraser (2009) used a modified version of the WIHIC to assess a two-year mentoring programme in science for beginning teachers in an elementary school in southeastern USA. The sample was made up of seven beginning teachers and 573 elementary students. Based on MANOVA and effect sizes, the results supported the effectiveness of the mentoring programme in improving the classroom learning environment, students' attitudes and achievement (Pickett & Fraser, 2009).

In New York, Wolf and Fraser (2008) used the WIHIC to evaluate the effectiveness of using inquiry-based laboratory activities in terms of learning environment, attitudes and achievement. The sample consisted of 1,434 middle-school students in 71 science classes. The study reported that inquiry-based instruction promoted more Student Cohesiveness than non-inquiry instruction and that inquiry-based instruction was differentially effective for male and female students. Cohn and Fraser (2016) investigated the effectiveness of a Student Response Systems (SRS) using a modified version of the WIHIC called the How Do You Feel About This Class? (HDYFATC) questionnaire with 1097 students (532 students used SRS and 565 students did not use SRS). The results supported the efficacy of the SRS. Oser and Fraser (2015) compared 322 grade 8–10 students' perceptions of the learning environment, attitudes towards science and achievement in virtual laboratories and physical laboratories. The study showed no significant difference between the two instructional groups. However, the study showed significant instruction–sex interactions that suggested that virtual laboratories were advantageous for males but disadvantageous for females on several criteria.

Long and Fraser (2015) in Texas examined the effectiveness of two middle-school science curriculum models, namely, a general science model and a topic-specific model, among 367 grade 8 students. Where two groups of science students in different U.S. states were compared, the general curriculum was more effective for Hispanic students but the two science models were equally effective for Caucasian students.

Afari et al. (2013) used the WIHIC in the Arabic language with a sample of 352 college students from 33 classes in the United Arab Emirates. The study reported that the use of mathematics games fostered a positive classroom environment.

2.5.3 Improving Classroom Environments

Though there have been numerous studies of educational environments, very few of these studies aimed to help teachers to improve their classroom practice. Fraser (1981, 1986) has explained how feedback based on students' and teachers' perceptions can be reflected upon and discussed in order to identify systematic ways to improve classroom or school environment. Fraser and Fisher (1986) suggested the following five steps which the teacher can employ when using classroom environment instruments to inform changes in practice: (1) assessment, (2) feedback, (3) reflection and discussion, (4) intervention and (5) reassessment.

The research by Yarrow, Millwater and Fraser (1997) aimed at improving university and primary school classroom environments through 117 preservice education teachers' action research. The teachers were introduced to the field of learning environment and they employed the CUCEI and MCI at the university and primary school, respectively.

Feedback based on student or teacher perceptions has been used to improve classroom environments at almost all grade levels from the early-childhood to higher-education level (Fisher, Fraser & Bassett, 1995; Fraser & Deer, 1983; Thorp, Burden & Fraser 1994; Woods & Fraser, 1996). First, the preferred form of the classroom environment is administered followed by the actual form a week later. The scales which show a wider gap are usually the areas where intervention by the teacher is provided. A student actual form is re-administered to identify any differences in students' perceptions (Woods & Fraser, 1996).

There are other similar studies in which the learning environment instruments have been used by teachers to improve their classroom environments in Australia. Aldridge et al. (2012) used the COLES in a large-scale investigation in Western Australia to study the effectiveness of using student perceptions for developing teacher expertise and improving classroom practice. Aldridge et al. (2004) administered the CLES to 1864 students in 43 classes to obtain feedback aimed to promote reflective practice among South African teachers in the mathematics classroom.

2.5.4 Other Types of Learning Environment Research

Fisher and Fraser (1983a) used the ICEQ to measure differences between students' and teachers' perceptions of the classroom environment. The study indicated that students preferred "a more favourable classroom environment than was perceived as being actually present" (Fisher & Fraser, 1983a, p. 55) and that teachers perceived the environment their classes more favourably than did students in the same classrooms. Similar results were seen in some of the earlier studies by Moos (1979) and Wubbels, Brekelmans and Hooymayers (1991). Using actual and preferred forms of classroom environment instruments, it can be determined if a closer similarity between actual and preferred can lead to better student outcomes. Fraser and Fisher (1983a, 1983b) found that actual-preferred congruence can be a predictor of student achievement of affective and cognitive outcomes.

Studies of classroom learning environments have combined quantitative and qualitative methods (Fraser & Tobin, 1991; Tobin & Fraser, 1998). Questionnaires assessing student perceptions of classroom psychosocial environment complemented the qualitative data derived from interviews and classroom observations (Fraser, 1996; Fraser & Tobin, 1991; Tobin, Kahle & Fraser, 1990).

Although school psychologists traditionally have focused on improving academic and other valued outcomes, attention to learning environments provides an opportunity also to focus on the processes in classroom life as a guide to improvements in classrooms (Burden & Fraser, 1993). Systems-orientated psychologists can employ learning environment questionnaires to assess students' perceptions of their teaching–learning contexts. This source of data allows psychologists to provide holistic educational advice and recommendations rather than solely relying upon within-child variables.

Most studies of learning environment mainly focus on a single environment, but it is possible to link and study the influence of two or more environments, such as school-level environments and classroom-level environments (Dorman, Fraser, & McRobbie, 1997; Fraser & Rentoul, 1982), home and school environments (Marjoribanks, 1991), school, family and work environments (Moos, 1991) and class, home and peer environments (Fraser & Kahle, 2007).

Cross-national studies (Aldridge et al., 1999) are potentially useful because there is a wider variation in teaching styles and student attitudes between countries than within a single community. Commonly-accepted educational practices, beliefs and attitudes in one country can be challenged by experiences in another country (Aldridge et al., 2000; Fraser, 1997; Fraser et al., 2010).

Learning environment dimensions have been used as dependent variables in studies of the transition between small primary and larger secondary schools (Ferguson & Fraser, 1996; Midgley, Eccles, & Feldlaufer, 1991). When Ferguson and Fraser (1996) investigated the differences in learning environment between primary schools and secondary schools, they found that students tended to perceive their secondary classroom environments less positively than their primary classroom environments. The research also showed that changes in perceptions during transition depended on school size and student gender.

Some attempts have been made to use learning environment case studies in preservice and inservice teacher education (Duschl & Waxman, 1991; Fraser, 1993). Learning environment dimension used in teacher assessment systems have revealed that competent teachers build good interpersonal relationships in the classroom and make students feel comfortable and acceptable (Ellett, Loup & Chauvin, 1989).

2.6 Student Attitudes

For the purpose and context of my study, the types of past research on learning environments were discussed comprehensively in the previous Section 2.5. Because the present study also included student attitudes as criteria in evaluating technology-based classrooms, Section 2.6.1 provides a literature review on definitions of attitudes. This is followed by Section 2.6.2 and Section 2.6.3 which provide a comprehensive overview of attitude questionnaires used in the past and the current research.

2.6.1 Definition of Attitudes

Attitude is central to human activity, yet it is not easy for educational researchers to comprehend it (Shrigley, 1983). Thurstone (1928) was the first to state that attitudes can be measured. Instead of gaining approval for his claims, he was criticised. He defined attitude as "the sum total of a man's inclinations and feelings, prejudice and bias, preconceived notions, ideas, fears, threats and convictions about any specified topic" (Thurstone, 1928, p. 531). Other researchers, over the years, have broadened and clarified Thurstone's definition. Attitude is an intangible psychological construct that can be inferred from demonstrated actions (Eccles, 2007; Mueller, 1986).

Attitudes are defined as individually-attributed beliefs, emotions and behavioural tendencies that an individual has towards specific abstract or concrete objects (Baron & Byrne, 1977). Kerlinger (1986) defined an attitude as "…an organized predisposition to think, feel, perceive, and behave toward a referent or cognitive object" (p. 453). Attitude is learned as part of culture and therefore is not innate (Shrigley, 1983). Reid (2006) explained that there are three components to attitudes: cognitive (knowledge of the object, belief or idea), affective (feelings regarding the object) and behavioural (the tendency towards action). Kind, Jones and Barmby (2007) define attitudes as feelings that a person has about an object based on beliefs that he or she holds about that object.

Fraser (1998b, 2007) and Walker (2006) reported that, though learning environments influence students' attitudes, attitude outcomes are often underemphasised relative to cognitive outcomes. Many studies reviewed in Section 2.5.1 have shown that positive learning environments can promote positive attitudes in students. Many studies have shown that the number of students pursuing science education has declined (Bybee, 1994; Hilton et al., 1989; National Science, 1983; Osborne & Simon, 1996). Misiti, Shrigley and Hanson (1991) reported that attitudes formed during middle-school years influence science course choices in high school and college. Many past studies have reported that career choices will only be science-related if students develop a positive attitude towards science in schools (Hofstein & Walberg 1995; Lowe, 2004; Ormerod & Duckworth, 1975; Osborne & Simon, 1996). For these reasons, it is pertinent to continue to research attitudes with the use of suitable instruments and to examine associations between the learning environment and student attitudes.

Perrodin (1966) started the first research into science attitudes in USA when elementary-school science students' attitudes towards science education were investigated. The research was undertaken using qualitative methods. A large sample comprising 500 statements obtained from students in grades 4, 6 and 8 were transcribed and analysed to derive conclusions about student attitudes towards science (Perrodin, 1966).

In a study conducted in Singapore, Caleon and Subramaniam (2008) found that boys generally reported more positive attitudes towards science than girls, although the difference is small and less prominent for gifted students. Similarly, the reports of TIMSS 1995 and 1999 pertaining to Singapore students reveal that girls had less positive beliefs in their abilities in science compared with boys (Martin et al., 2000).

Later, in 1970, the first instrument to measure attitudes towards science, the Scientific Attitude Inventory (SAI), was designed by Moore and Sutman (1970) in the USA. The instrument assessed secondary-school students' knowledge of scientific laws and theories, as well as their feelings about being a scientist. For several years, the SAI was the main instrument used in over 30 studies throughout the world, but the validity of this instrument was in doubt (Munby, 1983). The SAI was revised by Moore and Fay (1997) to form the SAI II, by gathering feedback and suggestions from researchers who had used it. The modified instrument was validated among 557 students in grades 6, 9 and 12. The improved version was shortened to 40 items, instead of the 60 items in the original SAI, and statements were re-worded to remove gender-biased language.

There are various ways of assessing attitudes towards a subject such as interviews, open-ended questions, projective techniques, closed-item questionnaires, and preference ranking (Laforgia, 1988). A number of instruments have been designed to elicit students' attitudes towards a subject (Fisher, 1973; Fraser, 1978, 1981; Mackay, 1971; Walker, 2006) but some of these instruments have been criticised on conceptual and empirical grounds (Gardner, 1975; Munby, 1980; Schibeci, 1984).

Another instrument that has contributed significantly to the study of attitudes towards science is the Test of Science-Related Attitudes (TOSRA) developed by Fraser in 1981. This instrument was designed to address potential problems related with the use of existing instruments which demonstrated low statistical reliability and construct validity, lack of clarity in the construct being assessed, and the invalid practice of combining conceptually-distinct constructs into one scale (Fraser, 1978). The TOSRA has 70 items (10 items in each of 7 scales), based on Klopfer's (1971) categories of affective behaviours in science education. The seven distinct scales in this instrument, which are suitable for use with secondary-school students, are Social Implications of Science, Normality of Scientists, Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lesson, Leisure Interest in Science and Career Interest in Science. The TOSRA uses a five-point response format ranging from Strongly Agree to Strongly Disagree. Each scale's polarisation is balanced, with each scale having five positive items and five negative items.

The TOSRA was first field tested in Australia among 1,337 students in 44 classes from 11 different schools (Fraser, 1981). Later several other studies confirmed its validity and reliability in Australia (Fraser et al., 2010; Fraser & Butts, 1982; Schibeci & McGaw, 1981), the United States (Lightburn & Fraser, 2007; Peiro & Fraser, 2009), Singapore (Peer & Fraser, 2015; Wong & Fraser, 1996) and Indonesia (Fraser et al., 2010). When Munby (1983) reviewed 56 science attitude instruments, he reported that TOSRA is an exceptionally well-developed instrument.

Student attitudes in science classrooms are relevant to my study because two of my research aims relate to student attitudes. The first aim was to investigate differences in students' attitudes in technology-based science classroom and regular science classroom. The second aim was to investigate associations between students' perceptions of the classroom environments and their attitudes. The scales in the attitude questionnaire used in my study were selected from the Attitude and Efficacy Questionnaire (AEQ) and Students' Adaptive Learning Engagement in Science (SALES) questionnaire. These two questionnaires are discussed in detail in Section 2.6.2 and 2.6.3, respectively.

2.6.2 Attitude and Efficacy Questionnaire

Aldridge and Fraser (2008) developed and validated the Attitude and Efficacy Questionnaire (AEQ) for "assessing students' attitudes, monitoring changes in attitudes over time, and investigating associations between student attitudes and the classroom learning environment" (p. 15), using a sample from a senior college in Australia. The three scales in this questionnaire are Attitude to Subject, Attitude to Computer Use and Academic Efficacy. Each of the scales contains eight items and five-point response alternatives (Almost Never, Seldom, Sometimes, Often and Almost Always).

The Attitude to Subject scale in the Attitude and Efficacy Questionnaire was modified from the TOSRA's Enjoyment of Science Lessons Scale because the TOSRA has exhibited sound validity and reliability in many past studies (Fraser, 1981; Fraser & Butts, 1982; Lin & Crawley, 1987; Beverly & Farenga, 1999; Lott, 2003).

Academic Efficacy was selected from the Morgan-Jinks Student Efficacy Scale (MJSES) designed by Jinks and Morgan (1999). Bandura (1986) defined self-efficacy as the judgement that people make about their ability to use their skills and it refers to the extent to which they are confident in their ability. Past studies have reported "that high self-efficacy positively affects engagement, effort, persistence, goal setting and performance" (Bandura, 1982, 1989; Schunk, 1989; Zimmerman, Bandura, & Martinez-Pons, 1992).

The Attitude to Computer Use scale was based on the Computer Attitudes Survey (CAS) which was designed by Loyd and Gressard (1984), and later modified by Newhouse (2001), to assess students' attitudes towards computers and computer programmes. The original version of CAS containing 30 positively-worded and negatively-worded items was reported to be reliable and effective. Eight items were selected and adapted to form the Attitude to Computer Use scale in the AEQ (Aldridge & Fraser, 2008). This new scale was positively worded to assess students' enjoyment or anxiety associated with using computers.

"Past studies have indicated that institutions that provide easy access to computers could foster positive attitudes (Mitra & Steffensmeier, 2000; Teo,

2006) towards the use of computers. According to Liu, Macmillan & Timmons (1998), students who have positive attitudes towards computers are more likely to have positive attitudes towards using computers in their learning" (Aldridge & Fraser, 2008, p. 30).

The Attitude to Computer Use scale was renamed the Attitudes towards Computers scale and used in my study because one of my objectives was to assess students' confidence in using computers in either technology-based science classrooms or regular science classrooms. The scale can be found as part of the attitude questionnaire in Appendix B.

2.6.3 Students' Adaptive Learning Engagement in Science Questionnaire

The Students' Adaptive Learning Engagement in Science (SALES) questionnaire was designed to assess students' motivation and self-regulation in science learning (Velayutham et al. 2011). In educational psychology, 'adaptive' describes characteristics that promote students' engagement in learning (Ames, 1992; Dweck, 1986; Kaplan & Maehr, 2007; Midgley, 2002; Pintrich, 2000). One of the greatest challenges that teachers face is stimulating students' motivation to learn (Theobald, 2006). Motivation is a key dimension of attitudes (Tapia & Marsh, 2004) that instigates and focuses goal-oriented behavior (Schunk, 2004).

Zimmerman (2002) indicated that three components of motivation have consistently been associated with students' adaptive motivational beliefs—learning goal orientation, task value and self-efficacy—and that each is integral to successful engagement in self-regulated learning. The ability of students to self-regulate their learning has been identified as a central construct that influences students' engagement in learning and their achievement in school (Boekaerts & Cascallar, 2006). According to Pintrich (2000), both adaptive motivational beliefs and adaptive self-regulated learning foster students' engagement in classroom activities.

The SALES questionnaire contains four scales, Learning Goal Orientation, Task Value, Self-efficacy and Self-regulation. For each scale, there are 8 items and respondents are given five alternatives for each item (Almost Never, Seldom, Sometimes, Often, and Almost Always). The SALES is a relatively new instrument that was validated with a sample of 1360 Grade 8 to 10 students in 78 classes from five different public schools in Australia (Rogers, 2013; Velayutham et al., 2011). It has been used in one study undertaken in Florida, USA (Koren, 2013).

The first scale in the SALES, Learning Goal Orientation, measures students' adaptive motivational belief in science learning. This scale was included because researchers have defined goals as an intellectual depiction of what individuals are trying to achieve and their reasons for undertaking a task (Pintrich, 2000). Learning goal orientation focuses on learning, understanding, mastering tasks, use of standards of self-improvement, progress and deep understanding of task (Pintrich, 2000). Past studies have reported that learning goal orientation can influence a range of positive learning outcomes including student achievement (Brookhart, Walsh, & Zientarski, 2006; Kaplan & Maehr, 1999, 2007) and students' attitudes and achievement in science (Tuan, Chin & Shieh, 2005).

For the other scales selected for my study, a discussion is provided in Sections 2.6.3.1, 2.6.3.2 and 2.6.3.3, respectively.

2.6.3.1 Task Value

Task Value is the value that students place on the science tasks given to them (Velayutham et al., 2011) and it influences students' attitudes towards science and science achievement (Tuan et al., 2005). Students who believe that their learning activities are important, interesting and useful persevere and spend more effort to understand and finish the tasks (Pintrich & De Groot, 1990; Wolters & Rosenthal, 2000). Schunk and Zimmerman (2007) reported that students can persist on tasks if they consider them to be important even though they have low self-efficacy. This scale was selected for my study because one of my foci was to investigate whether students perceived science as relevant and whether there were differences between technology-based science classrooms and regular science classrooms for this attitude.

2.6.3.2 Self-Efficacy

Self-efficacy is students' self-belief that they can achieve the desired outcomes and it is a strong predictor of student choices, effort and persistence (Velayutham et al., 2011). Self-efficacy varies with contexts in that high self-efficacy in one subject does not mean high efficacy in another subject (Bandura, 1986, 1989; Pintrich & Schunk, 1995). Pajares (1996) reported that greater self-efficacy is associated with greater student willingness to persevere in challenging tasks and better academic performance. Self-efficacy has been found to be a stronger predictor of achievement and engagement in science than sex, ethnic background or parental background (Kupermintz, 2002). This scale was chosen for my study because I was keen to know if there were differences between technology-based science classrooms and regular science classrooms in students' belief in their own ability.

2.6.3.3 Self-Regulation

Self-regulation is the degree to which students engage in their learning and evaluate their progress (Velayutham et al., 2011). Boekaerts and Cascallar (2006) argue that students' self-regulation in classrooms is the most important influence on students' engagement in learning and achievement. The key aspect of self-regulation is that students employ cognitive and motivational strategies to achieve learning goals (Boekaerts & Cascallar, 2006). Zimmerman (2000) reported that motivation is a prerequisite for self-regulation. He explained that learning goal orientation, self-efficacy and task value are the three components of motivation linked to self-regulation.

Past studies have shown that higher self-regulation skills lead to academic motivation (Pintrich, 2003). Perels, Gurtler and Schmitz (2005) found that short interventions for improving student self-regulation can result in increased students' self-efficacy. The self-regulation scale was chosen for my study because I wanted to assess if there were differences between technology-based science classrooms and regular science classrooms in students' motivation to study science.

2.7 Summary of the Chapter

The purpose of this chapter was to review literature related to gifted education, learning environment and student attitudes, which are the three main areas relevant to my study. Section 2.2 described the history of the field of gifted education, including conceptions of giftedness, the development of gifted education, the education system and gifted education in Singapore, and the science curriculum for the gifted. Giftedness in the human race was recognised long before the nineteenth century in ancient civilisations such as in China, Turkey, Rome and Greece. Galton (1869) stated that intelligence was inherited through natural selection, with the psychology of individual differences and the quantitative analysis of human intelligence being two of the many legacies of Galton (Silverman, 2013). Binet and Henri's work was the first step towards the creation of the first scale to measure intelligence as a single numerical outcome. Goddard in 1908 was satisfied with the intelligence test, popularised it by distributing copies to American educators and psychologists, advocated its use in public schools throughout United States, and popularised the Binet scales (Plucker & Esping, 2014).

Wechsler (1939) developed another instrument to measure intelligence because he felt that existing instruments had too much emphasis on verbal attributes. He revised the test in 1942 and published the Wechsler Intelligence Scale for Children in 1949. In 1915, Terman wrote a paper called 'The Mental Hygiene of Exceptional Children' in which he stated that, though giftedness is inherited, it requires nurturing to reach its potential and therefore schools should cater for the development of children with exceptional intelligence. Between 1901 and 1956, special schools and classes for the gifted were started by Hollingworth. The launching of the Russian satellite in 1957 re-kindled interest in gifted education in America but, in 1964, the Civil Rights Act, which emphasised equal education for all, halted development in programming for the gifted. The next wave of interest in gifted education started in 1972 following the Marland Report, the first national report on gifted education by the USA Department of Education to the Congress of the United States. However, in 1975, The Education for all Handicapped Children Act established a federal mandate to serve children with special education needs, but did not include children with gifts and talents. In 1983, a national report disclosed that the brightest in America are not achieving as well as students in other countries. The report published policies and practices in gifted education and promoted suitable programming for the gifted. In late 1990s, gifted education policies based on credible educational and psychological theories were established, and provisions for programming for the gifted and talented were carefully planned and implemented in schools.

The education system in Singapore was first designed to provide each child with a basic education so that he or she can contribute to the economy of the country. The Ministry of Education has a commitment to recognise, nurture and develop the potential of each pupil. In Singapore, pupils are identified for the Gifted Education Programme (GEP) based on their performance in selection tests, which are conducted at the end of Primary 3. In Primary 6, GEP pupils take the same Primary School Leaving Examination as the mainstream pupils and get directed to secondary schools based on their scores. Singapore has a strong education system that aims to help students to discover their own talents, make the best of these talents to realise their full potential and develop a passion for lifelong learning. It is hoped that a person who has been part of the Singapore education system will be confident, a self-directed learner, an active contributor and a concerned citizen. Therefore the outcomes of education do not focus on just developing the academic potential of the students but also place a considerable emphasis on developing the skills, character and values that enable students to continue to do well and take the country forward in the future.

The Ministry of Education of Singapore designs the science syllabus which extends from the Primary to the Pre-University Level. This syllabus is based on a Science Curriculum Framework that aims to provide a balance between the acquisition of science knowledge, skills and attitudes. The science syllabus for gifted students is made more advanced to match their intellectual abilities. Though the same topics are taught, they are differentiated to include more depth and breadth in content. As a result, assessments for the gifted are different from those for mainstream pupils because the former includes more higher-order thinking questions.

Section 2.3 reviewed the history of the field of learning environments. Research on educational environments stems from contributions by human psychologists, Lewin (1936), Murray (1938) and their proponents. Lewin (1936) theorised that $B = f(P, E)$, where Behaviour (B) is a function (f) of the person (P) and his/her environment (E). Murray (1938) developed Lewin's theory further to include the idea of personal needs of an individual and the environmental press. Murray also contributed the concept of *alpha press* and *beta press* which was further developed by Stern et al. (1956). Walberg designed the Learning Environment Inventory (LEI) to assess a curriculum development project in the USA (Walberg & Anderson, 1968). Moos (1979) first designed social climate scales to be administered in psychiatric hospitals and correctional institutions, and this eventually guided the design of the Classroom Environment Scale (CES) (Moos, 1979; Moos & Trickett, 1987).

Section 2.4 reviewed a range of learning environments questionnaires. Since the pioneering work of Walberg and Moos, major research programmes have been conducted on classroom environment, including the conceptualisation and development of other learning environment instruments (Aldridge et al., 2004; Aldridge et al., 2012; Fraser, 1986, 1991, 1994, 1998a, 2014; Goh & Khine, 2002). Different instruments that have been developed and validated in studies worldwide were discussed in detail in this section: LEI, CES, ICEQ, MCI, CUCEI, QTI, SLEI, CLES, WIHIC, TROFLEI and COLES.

Section 2.5 reviewed various types of research involving learning environment and how the versatility of learning environment instruments has supported a variety of studies in educational institutions worldwide. The questionnaires have served researchers well for evaluating innovative programmes in school, studying associations between learning environment and student outcomes, action research by teachers and numerous other research objectives.

Section 2.6 reviewed literature on student attitudes. Section 2.5.1 illustrated how numerous studies revealed associations between the classroom environment and student attitudes towards science (Fraser, 2012, 2014). My study also focused on relationships between students' perceptions of their learning environment and their attitudes. Therefore, definitions of attitude provided by Thurstone (1928), Baron and Byrne (1977), Shrigley (1983) and Kerlinger (1986), together with instruments for measuring attitudes, were reviewed. The section concluded with a detailed review of literature concerning the scales used in the attitude questionnaire in my study. The scales selected for my research were Attitudes towards Computers from the AEQ (Aldridge & Fraser, 2008), Task Value, Self-efficacy and Self-regulation from the SALES (Velayutham et al., 2011).

The next chapter, Chapter 3, describes in detail the methodology employed in the present study, including sample selection, the instruments employed to gather the data, field-testing of the questionnaire, ethical considerations, the data-collection process and the methods used to analyse the data.

Chapter 3
METHODOLOGY

3.1 Introduction

This chapter explains the methods employed in my investigation. In Section 3.2, the objectives of the study and research questions are recapitulated. Section 3.3 describes the field-testing of the questionnaire in the population to be studied. The background and selection of study participants is recounted in Section 3.4. Ethical considerations in this study and the security of the research records are discussed in Section 3.5. The instruments from which the scales were selected when designing the questionnaire used in this research are discussed in Section 3.6. The steps taken when collecting the quantitative data are explained in Section 3.7 and how the data were analysed to address the research questions is described in Section 3.8. Finally, Section 3.9 provides a summary of this chapter.

3.2 Research Objectives

As stated in Chapter 1, the objectives of the proposed study were to investigate:

- whether the questionnaire assessing learning environment and attitudes are valid and reliable when used with gifted female students in a secondary school in Singapore;
- differences between technology-based science classrooms and regular science classrooms in terms of students' attitudes and perceptions of classroom learning environment;
- associations between students' perceptions of classroom learning environments and their attitudes.

After a thorough review of the literature about various instruments used in past research, I found that the learning environment scales in the TROFLEI (Dorman, et al., 2006) and COLES (Aldridge et al., 2012) were most suitable for measuring the learning environments in gifted classrooms in my study. I chose five scales from the TROFLEI and one scale on assessment of student learning from the COLES because these scales are aligned to the instructional processes proposed by Van Tassel-Baska and Stambaugh (2006) to facilitate curriculum experiences for the gifted.

Past research shows that the learning environments designed by teachers have an influence on students' attitudes (Fraser, 2014; Walker, 2006). The assessment of attitudes and their associations with the learning environment were also part of this study. Four attitude scales were identified, one scale from the AEQ (Aldridge & Fraser, 2008) and three scales from the SALES (Velayutham et al., 2011). A total of ten scales, six assessing learning environment and four assessing attitudes, were selected and used.

Any questionnaires used in research should be valid and reliable in measuring what they intend to measure. Once the validity of questionnaire is established, responses to the surveys can then be used to address the rest of the research question in a study. Therefore the first research question was:

Research Question # 1

Are learning environment scales based on the TROFLEI and COLES and attitude scales based on the AEQ and SALES valid and reliable when used with gifted female students in a secondary school in Singapore?

Once the questionnaire were validated, differences between technology-based science classrooms and regular science classrooms in terms of students' attitudes and perceptions of classroom learning environment were examined. Therefore, the second research question was:

Research Question # 2

For gifted female students in Singapore, do scores on attitude and learning environment scales vary between technology-based and regular science classrooms?

Lastly, investigating relationships between the learning environment and attitudes was the focus in research question 3:

Research Question # 3

Are there associations between students' perceptions of classroom learning environments and their attitudes among gifted female students in a secondary school in Singapore?

3.3 Pilot Study

In any research, it is pertinent to carry out a pilot test or a trial run to verify the face validity of the questionnaire before using them in the main research study. A common practice prior to the formal gathering of data is to try out the data-collection techniques for the quantitative data and to provide an estimate of the time needed for students to respond to questionnaire. The appropriateness of questionnaire also can be assessed in terms of misunderstandings, ambiguities or other inadequacies when administered in the population to be studied (Ary, Jacobs, Razavieh & Sorensen, 2006).

My questionnaire was distributed to three teachers with a minimum of three years of experience in the school with a request for them to identify any confusing items. They were also asked to suggest changes in the wording to improve clarity and to better suit the school's formal language and cultural context. Based upon changes recommended by the teachers, ten items (Statement numbers 31, 41, 42, 43, 44, 45, 46, 47, 48 and 75) were modified, taking care not to jeopardise the face validity of the items before field-testing them with students.

The sample for this study was the entire cohort of Grade 9 and Grade 10 students whose average age was 15 years. So, a class of 33 students aged 13 to 14 years was chosen for the pilot study. The students in the pilot test also were adolescents and were deemed to be similar to the students in the sample for the main research. The questionnaire was printed and given to the students and the time taken for all the students to complete the survey was noted. It took around 8 minutes for the students to respond to all the items in the survey.

Although the questionnaire was administered electronically in my main study, it was a deliberate decision to carry out the pilot study using hard-copy questionnaire. This was to facilitate an interview session with the students after completion of the questionnaire. The students were asked to revisit the 80 items again and circle those found to be ambiguous or confusing. They were also asked to highlight the items for which their responses were `Not Sure'.

In the interview session, the students were asked if the instructions for how to respond to the questionnaire were clear. The purpose of the questionnaire was explained and any confusing item was re-worded. Students who had no problems with interpreting the items were asked to explain their interpretation of the items. Students also proposed words and phrases that would allow some items to be interpreted in a consistent manner and free from ambiguity. Further probing was made and each item was discussed to ensure common understanding, clarity and readability.

Based on the teachers' and students' feedback, Items 31 and 75 were reworded. An additional word,`assignments', was also added to 8 items (Statement numbers 41 to 48) in the Formative Assessment scale. The changes made are shown in Table 3.1.

Table 3.1: Changes to Questionnaire

Statement Numbers	Original Statement	Modified Statement
31	I use different assessment methods from other students.	For some assessments, I choose a type of presentation that is different from that chosen by other students.
41 to 48	….assessment tasks………	..assessment tasks/assignments..
75	I get myself to learn even when there are other things to do.	I get myself to learn even when there are other things to do (e.g. reading a novel, Facebook).

3.4 Study Participants

The student participants in this study were high-ability learners who were among the top 1% to 3% scorers in Singapore's national examination for primary school leavers. They attended a private school in Singapore for high-ability learners where the curriculum framework follows the Integrated Curriculum Model for the gifted by Van Tassel-Baska (1987). Upon receiving an ethics approval number from Curtin University, as well as approval from the school principal, I compared students in technology-based and regular science classrooms.

The selected sample consisted of 777 students, with 409 students enrolled in Grade 9 technology-based science classes and 368 students enrolled in Grade 10 in regular science classrooms. The age of student respondents ranged from 14 to 16 years. The students were in self-contained classrooms with a class size of 30 to 35 students. There were 14 technology-based classes and 13 regular science classes. The estimated sample size allowed for attrition, misadventure and other potentially hampering circumstances. Of the selected sample, 722 students consented to take part in the survey, which is almost 93% of the selected cohort. Complete and usable responses were obtained from 379 students from the technology-based classrooms and 343 students from the regular science classrooms (i.e. a total of 722 students).

3.5 Ethical Considerations

Given that this study involved humans, I fully accepted the responsibility that I was both ethically and legally bound to protect participants from any potential harm or forms of abuse that might arise as a result of participating in this study. In addition to abiding by and working within the parameters established for the ethical protocols by Curtin University, I also adhered with the school's published guidelines and protocols for conducting educational research.

I received an ethics approval number SMEC-33-13 from the Human Research Ethics Committee at Curtin University (see Appendix G). I also applied for approval from the Principal of the school involved in my study (see Appendix F).

Written communication, in the form of a letter, was emailed to the Principal of the school involved in my study. The letter provided a brief description of the research problem, presented an overview of the tools that would be used when conducting the study, and explained the amount of time needed to devote to the study. Follow-up communication was made using a personal e-mail system and via telephone. Once permission was obtained from the Principal, I strictly abided by the ethical guidelines set forth by Curtin University's Human Research Ethics Committee for research involving humans.

The purpose of the research and students' involvement in the study was explained to the students and their parents/legal guardians by means of a written letter (see Appendices B and D). A written and signed consent form from parents/legal guardians was required prior to any student's participation (see Appendix C). This was an essential step, given that all students in the sample were minors. Any student who did not receive written consent from her parent/legal guardian was not permitted to participate in the study. Furthermore, the letter advised both students and their parents/legal guardians of the intentions of the study and my role as the researcher. The letter indicated clearly that students' participation was voluntary and that they may elect to withdraw from and discontinue their involvement in the study at any time (see Appendix E).

The confidentiality of students' data was ensured; students' anonymity was guaranteed by coding all participants using numeric values so as to remove identifying features from the data during data preparation and entry. Lastly, the letter advised parents that feedback on the progress of the study would be forthcoming in written form.

All electronic questionnaires and completed responses were stored on my personal computer, which could only be accessed with a password and which would be deleted at the conclusion of this study. All 'hard copy' items were stored in a locked cupboard at my home. The electronic data stored on a computer hard-drive was accessible only to me and members of my thesis committee while analyses were being completed. The data files will be maintained electronically for seven years at Curtin University after which time they will be destroyed.

3.6 Instruments Used in Study

3.6.1 Learning Environment Scales

To assess the present-day classroom that infuses technology into the curriculum and that focuses on outcomes-based education, Aldridge et al. (2004) developed and validated a new contemporary classroom environment instrument, the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI), using a multi-trait–multi-method model. The questionnaire is an extension of the commonly-used learning environment instrument, What Is Happening In this Class? (WIHIC), which provides a focus on technology and outcomes-focused education.

The TROFLEI includes the seven scales in the WIHIC which was designed by Fraser et al. (1996). The WIHIC is extensively reviewed in Chapter 2, Section 2.4.9. As well, the three additional classroom environment dimensions of Differentiation, Computer Usage and Young Adult Ethos are included in the TROFLEI. In other words, this instrument contains 10 scales with 8 items each. To identify if the teacher caters for individualism, a Differentiation scale was adapted from the Individualised Classroom Environment Questionnaire (ICEQ; Fraser, 1990). The extent and the variety of ways in which computers are used in the classroom can be assessed using the Computer Usage scale. A Young Adult Ethos scale was included to assess opportunities provided by teachers for self-directed learning. The TROFLEI is a suitable instrument to measure the learning experiences in gifted classrooms because the scales are aligned with the instructional processes proposed to facilitate curriculum experiences for the gifted (Van Tassel-Baska & Stambaugh, 2006). The questionnaire used in my study included 5 scales from the TROFLEI.

The TROFLEI has been validated in numerous studies undertaken in Australia (Aldridge et al., 2004; Aldridge & Fraser, 2008; Aldridge et al., 2012), New Zealand (Koul et al., 2011), Turkey (Cakir, 2011; Welch et al., 2012) and the USA (Earle & Fraser, 2016; Welch et al., 2012). A comprehensive review of the TROFLEI is found in Chapter 2, Section 2.4.11.

Because all the existing classroom environment questionnaires exclude scales related to the assessment of student learning, which are useful for informing learners of their progress in learning, one additional scale on assessment of student learning from Constructivist-Orientated Learning Environment Survey (COLES) was incorporated into the learning environment questionnaire in my study. The COLES was designed by Aldridge et al. (2012) to assist teachers in their action research so that they can improve their students' classroom experience. This instrument contains mostly the scales from the WIHIC but also includes scales to appraise assessment of student learning. There has been validated in high schools across Western Australia (Aldridge et al., 2012). The COLES is reviewed in detail in Section 2.4.11 of Chapter 2.

The school for high-ability learners, where my study took place, has developed a curriculum that emphasises higher-order thinking, self-directed learning, collaboration, differentiation, digital literacy and formative assessment. This justifies my choice of five scales from the TROFLEI and one scale on assessment of student learning from the COLES because the learning environment scales are aligned to the curriculum emphasis for the high-ability learners in the school.

Table 3.2 shows the instruments and scales chosen to assess the learning environment in my study. The learning environment questionnaire used in my study is found in Appendix A.

3.6.2 Attitude Scales

Past research shows that the learning environment has an influence on students' attitudes (Peer & Fraser, 2015; Peiro & Fraser, 2009). A comprehensive review of the definition of attitudes and scales used in assessing this human behaviour is found in Chapter 2, Section 2.6. My study focused on four important aspects of students' attitudes: attitudes towards computers, perceiving science as relevant, belief in one's own ability, and motivation to study science. The scale to assess attitudes to computers use was based on the Attitude and Efficacy Questionnaire (AEQ) (Aldridge & Fraser, 2008). A scale to assess attitude to computer use was derived from the Computer Attitudes Survey (CAS) (Loyd & Gressard, 1984; Newhouse, 2001).

Studies showed that schools that provide students access to computers promote positive attitudes towards their use (Mitra & Steffensmeier, 2000). The other three attitudes were measured using scales in the SALES questionnaire, developed by Velayutham et al. (2011). A review of the AEQ and SALES is found in Sections 2.6.1 and 2.6.2 of Chapter 2. Table 3.3 shows the student attitudes assessed in this study and the relevant scales chosen to measure them.

Table 3.2: Instruments and Scales Chosen to Assess the Learning Environment

Desired Classroom Elements	Instrument and Scale	Description of Scale
Higher-order Thinking	TROFLEI Investigation	The extent to which students are given opportunities to evaluate problems, analyse generated ideas and synthesise information
Self-directed Learning	TROFLEI Task Orientation	The extent to which the students perceive the importance of completing planned activities on their own and staying on the subject matter
Collaboration	TROFLEI Collaboration	The extent to which students cooperate rather than compete with one another on learning tasks
Differentiation	TROFLEI Differentiation	The extent to which students perceive that teachers cater for students differently based on students' capabilities and interests
Digital Literacy	TROFLEI Computer Usage	The extent to which students use their computers as a tool to communicate with others and to access information
Formative Assessment	COLES Formative Assessment	The extent to which students feel that the assessment tasks given to them make a positive contribution to their learning

Adapted from (TROFLEI, Dorman et al., 2006) and (COLES, Aldridge et al., 2012)

The questionnaire retained the original positively-worded items because past studies have shown that this promotes response accuracy and internal consistency (Schriesheim, Eisenbach & Hill, 1991; Schriesheim & Hill, 1981). All the 8 items in each scale were grouped together in a block rather than arranging them randomly or cyclically to provide contextual prompts, reduce confusion among students and ensure response assertiveness (Aldridge et al., 2000). The attitude questionnaire used in this study is found in Appendix A. The scale taken from the AEQ was validated in the study by Aldridge and Fraser (2008) and the scales selected from the SALES were validated in two studies undertaken in Australia

(Rogers, 2013; Velayutham, Aldridge, & Fraser, 2012) and one in the United States of America (Koren, 2013); each of these studies was reviewed in Chapter 2, Sections 2.6.2 and 2.6.3.

Table 3.3: Instruments and Scales Chosen to Assess the Student Attitudes

Student Attitudes	Instrument and Scale	Description
Confidence in Using Computers	AEQ Attitudes towards computers	The extent to which students have a positive attitude and confidence in using computers to perform learning tasks
Perceiving Science as Relevant	SALES Task Value	The extent to which the student perceives the science learning tasks in terms of interest, importance and utility
Belief in One's Own Ability	SALES Self-efficacy	The extent of the students' confidence and beliefs in their own ability in successfully perform science learning tasks
Motivation to Study Science	SALES Self-regulation	The extent to which the students control and regulate their effort in science learning tasks

Adapted from (AEQ, Aldridge & Fraser, 2008) and (SALES, Velayutham et al., 2011)

3.7 Data Collection

Permission was sought from the Principal of the school for the questionnaire to be administered online using the school's portal. A meeting was arranged with the IT personnel assigned to help me so that we could discuss what I intended to do. Information about instructions for student participants was provided together with a soft-copy of the 80-item questionnaire for transfer to the school's online portal. Some missing information was spotted in the questionnaire and this could lead to a lack of clarity once it was transferred to the online platform. I highlighted the mistakes to the IT personnel who soon rectified them. The guidelines for students were also modified to avoid any confusion for the survey participants. The instructions for participants about how to complete the questionnaire were also revised accordingly. The final electronic version of the questionnaire was designed and placed on the students' portal.

Once the survey was ready to be administered, I met the Head of Science and the science teachers to brief them about my intention to collect data using the online survey. Based on past experience, submission rates are low when students are asked to complete online surveys in their own time. This usually requires teachers to track and send multiple reminders to students to finish surveys. In the pilot study, the questionnaire took around 8 minutes to complete. The teachers unanimously agreed to administer the questionnaire during lesson time because the time taken to complete them is very short and it was far more time efficient to supervise the administration of the survey in class to ensure that most, if not all, participants completed the survey.

I emailed to the teachers clear guidelines about how and where to access the online survey so that they could guide the student participants. A schedule was drawn up in collaboration with the Head of Science for allocating a time for the students to provide their responses.

I allotted four to six weeks to receive responses to the questionnaire. Reminders were communicated by means of email and telephone calls to those teachers who had not administered the questionnaire. Additional reminders were made weekly as needed.

After administration of the survey, student responses were removed from the school's online portal and exported into Microsoft Excel document. The document was emailed to me for collation and analysis. Upon receipt of the returned materials, I checked students' responses for completeness and inconsistencies prior to data collation and analysis. This process was completed confidentially within the confines of my personal office at my home. I began checking as soon as the first batch of questionnaires was received and the process continued until all questionnaires were returned.

The use of this technology minimised errors caused by having to manually enter results into a database or statistical programme for analysis. To address the research questions, there is a need to generalise the findings to the population being studied. So, this research involved only quantitative data collection. Gall, Gall and Borg (2003) stated that, if a finding is measured, validated and generalisable, then that result can be generalised to all similar populations because actuality is independent of individual experience. The other advantages of a quantitative research approach are that it is precise, independent of the researcher and deemed to be highly credible with many school administrators. It is also a good way to obtain data when the study involves a large number of people. The inclusion of qualitative information in my study probably would have added insights (Tobin & Fraser, 1998), but it was not practical to collect qualitative information because of time constraints.

3.8 Data Analysis

The IBM SPSS Statistics 21.0 package was used to analyse the quantitative data in various ways in order to answer the research questions adequately. All questionnaires were checked for completeness and inconsistencies prior to data entry. Additionally, it should be noted that, to ensure that the 80-item version of the questionnaire comprising scales from the original versions of the TROFLEI, COLES, AEQ and SALES (ten scales with eight items in each scale) was appropriate for the students, minor modifications were made to the items. Of course, making modifications made it necessary to check that the questionnaire remained both valid and reliable.

In the next three sections, 3.8.1 to 3.8.3, a description of the statistical analyses employed to address the three research questions in my study is provided. The first objective was to examine the validity and reliability of the learning environment and attitude questionnaire. The analyses undertaken for instrument validation are discussed in Section 3.8.1. The second research question was to investigate differences between technology-based science classrooms and regular science classrooms in terms of students' attitudes and perceptions of classroom learning environment. The statistical analyses to determine differences are discussed in Section 3.8.2. The third research question focussed on associations between the classroom learning environment and student attitudes. The analyses for investigating associations are delineated in Section 3.8.3.

3.8.1 Instrument Validation

The first research question involved the validity and reliability of the learning environment and attitude questionnaire for gifted female students. The data obtained from 722 students in 27 classes in a Singapore school were analysed in several ways. The questionnaire was administered to 379 students from 14 technology-based classrooms in Grade 9 and 343 students from 13 regular science classrooms in Grade 10.

Principal axis factor analysis with varimax rotation and Kaiser normalisation was first conducted on the 48 items in six learning environment scales to identify a succinct set of factors. This analysis was performed to extract a factor structure and to check it against the *a priori* 6-scale structure of the learning environment scales in the questionnaire. Next, the internal structure of the 32-item, four-scale version of the attitude questionnaire was analysed to establish if all the items in one scale were measuring the same construct and if each scale was measuring a distinct construct. Again, principal axis factor analysis with varimax rotation and Kaiser normalisation was selected to extract a factor structure for the questionnaire and to check against the *a priori* 4-scale structure of the attitude questionnaire.

A factor loading of at least 0.40 on its own scale and less than 0.40 on each of the other five scales were the criteria applied to retain any item. The percentage of variance, total variance extracted with each factor and the eigenvalue for each scale were also calculated. Results of these analyses are reported in Section 4.2.1.

Next, internal consistency reliability, with individual and class mean as units of analysis, was calculated for each of the six learning environment scales and four attitude scales for the sample of 722 students in 27 classes. The Cronbach alpha reliability coefficient was used as an index of scale internal consistency. Discriminant validity, using the mean correlation of a scale with the other scales as a convenient index, was used to indicate the extent to which each scale measures a distinct construct. Lastly, one-way ANOVA for each learning environment scale was conducted to check whether the revised version of each questionnaire scale was able to differentiate between the perceptions of students in different classrooms. Section 4.2.2 reports the internal consistency reliability and discriminant validity for both the learning environment and attitude scales, together with one-way ANOVA results for the ability of learning environment scales to differentiate between classrooms. The eta^2 statistics from ANOVA for each scale indicated the proportion of variance explained by class membership.

3.8.2 Differences in Students' Attitudes and Perceptions of Learning Environment Between Technology-based and Regular Classrooms

The second research question involved differences between technology-based science classrooms and regular science classrooms in terms of students' attitudes and perceptions of classroom learning environment. MANOVA/ANOVAs and effect sizes were calculated to determine the statistical significance and magnitude of between-group differences. The six learning environment scales and four attitude scales were dependent variables, whereas instructional method (technology-based vs regular classes) was the independent variable. If the multivariate test using Wilks' lambda criteria revealed statistically-significant differences between groups for the whole set of dependent variables, the results of the univariate ANOVA for each individual dependent variable would be interpreted separately as recorded in Table 4.5.

An effect size is simply an objective and standardised measure of the magnitude of an observed effect (Field, 2009) and is independent of sample size. Cohen's *d* is a common measure of effect size that can be calculated by finding the difference between the means and dividing it by the pooled standard deviation (Cohen, 1988). “The pooled standard deviation is found as the root mean square of the two standard deviations” (Cohen, 1988, p. 44). Section 4.3 reports the statistical significance and effect size for the differences between technology-based and regular science classes for each learning environment and attitude scale.

3.8.3 Associations Between Learning Environment and Student Attitudes

The third research question involved associations between students’ perceptions of their learning environments and their attitudes. To investigate relationships between students’ perceptions of their classroom environments and their attitudes, simple correlation and multiple regression analyses were conducted with the individual as the unit of analysis. The simple correlation analysis provided information about the bivariate association between each student attitude and each learning environment scale. Multiple regression analysis was used to provide information about the joint influence of a set of correlated environment scales on each attitude and it reduced the Type I error rate. The standardised regression coefficient (β) was used to indicate the individual influence that each independent variable had on an outcome when the other independent variables were controlled. The results of these analyses are found in Section 4.4.

3.9 Summary of the Chapter

The learning environment questionnaire in my research included five scales from the TROFLEI and one scale on assessment of student learning from the COLES because these scales (namely, Investigation, Task Orientation, Collaboration, Differentiation, Computer Usage and Formative Assessment) are aligned with the instructional processes proposed to facilitate curriculum experiences for the gifted (Van Tassel-Baska, 1986). The attitude questionnaire incorporated four scales, one scale from the AEQ and three scales from the SALES (namely, Attitudes towards Computers, Task Value, Self-Efficacy and Self-Regulation).

A pilot study was conducted prior to the main research in order to check that the questionnaire, research procedures and techniques work satisfactorily and to ensure face validity. Following the administration of the questionnaire, students were interviewed independently to ascertain whether they understood the verbiage of the questionnaire and were able to respond without problems. Minor modifications were made to the questionnaire for better comprehension by students in the main study.

The selected sample for the main study consisted of 777 students, 409 enrolled in technology-based classrooms and 368 in regular science classrooms, in Grades 9 and 10. The age of student respondents ranged from 14 to 16 years. The students were in self-contained classrooms with a class size of 30 to 35 students. There were 14 technology-based classes and 13 regular science classrooms. There were 722 students consented to take part in the survey, which is almost 93% of the selected cohort. All student questionnaire responses were complete and usable. The responses were obtained from 379 students from the technology-based classrooms and 343 students from the regular science classrooms (making a total of 722 students).

The questionnaire was administered online on the school's portal. The student responses were exported into a Microsoft Excel document that was emailed to me for collation and analyses.

To assess the reliability and validity of the learning environment and attitude questionnaire, principal axis factor analysis with varimax rotation and Kaiser normalisation was conducted. Scale internal consistency reliability, discriminant validity and ability to differentiate between classrooms (for learning environment scales only) were also calculated. To investigate differences between technology-based science classrooms and regular science classrooms in terms of students' attitudes and perceptions of classroom learning environment, MANOVA and effect sizes were used to determine the statistical significance and magnitude of differences between the two groups of students. To investigate the relationships between students' perceptions of their classroom environments and their attitudes, simple correlation and multiple regression analyses were conducted with the individual as the unit of analysis.

Chapter 4 describes the statistical analyses of the data and reports the major findings for each research objective in my study.

Chapter 4
RESULTS AND ANALYSES

4.1 Introduction

Chapter 4 focuses on how the data collected for this research were analysed and reports findings for the three main objectives of investigating: (1) whether the questionnaire assessing the learning environment and student attitudes are valid and reliable among secondary school gifted female students in Singapore; (2) differences between technology-based science classrooms and regular science classrooms in terms of students' attitudes and perceptions of classroom learning environment; and (3) associations between the classroom learning environment and student attitudes.

As described in Chapter 3, Section 3.6, the questionnaire comprising six scales for assessing learning environment and four scales for assessing attitudes was administered to 722 students in 27 classes. Each scale consists of eight items, making a total of 80 items in the questionnaire.

Items 1 to 48 of the questionnaire evaluated students' perceptions of the following six dimensions of learning environment: Investigation, Task Orientation, Collaboration, Differentiation, Computer Usage and Formative Assessment. The respondents were asked to thorougly read each item and specify how often a practice occurs using a five-point frequency scale with the alternatives of Almost Never, Seldom, Sometimes, Often and Almost Always. See Section 3.6.1 in Chapter 3 for further information on the learning environment scales. Refer to Appendix 3 for a copy of the questionnaire.

Items 49 to 80 of the questionnaire assessed students' attitudes using four dimensions: Attitudes towards Computers, Task Value, Self-Efficacy and Self-Regulation. The respondents were asked to select their degree of agreement using a five-point Likert scale of Strongly Agree, Agree, Not Sure, Disagree, and

Strongly Disagree. See Section 3.6.2 in Chapter 3 for further details of the attitude scales and Appendix 3 for a copy of the questionnaire.

The findings in this chapter are reported in the following way. Section 4.2 reports the validity and reliability of the questionnaire. Section 4.3 presents the differences between technology-based science classrooms and regular science classrooms with regards to students' attitudes and perceptions of classroom learning environment. Section 4.4 reports relationships between the classroom learning environment and student attitudes in technology-based and regular science classrooms. Lastly, Section 4.5 summarises and concludes this chapter.

4.2 Validity and Reliability of Learning Environment and Attitude Scales

To address Research Question 1, all survey responses to the questionnaire from 722 students were analysed for factor structure.

Research Question 1

Are learning environment scales based on the TROFLEI and COLES and attitude scales based on the AEQ and SALES valid and reliable when used with gifted female students in a secondary school in Singapore?

The next section, 4.2.1, reports the factor structure and this is followed by the internal consistency reliability, discriminant validity and the ability of the learning environment scales to distinguish between classes in Section 4.2.2.

4.2.1 Factor Structure of Learning Environment and Attitude Scales

Checking the validity and reliability of my questionnaire in a Singapore secondary school context was crucial because the validity and reliability of any questionnaire used in research needs to be established within the context in which it is used so that results reported are credible. In this study, the questionnaire was used to obtain responses for answering the next two questions in my research. So, this step of ascertaining that the survey instrument is sound is imperative.

Factor analysis was first carried out on the 48 items in six learning environment scales to ascertain if the items in each scale are measuring the "same construct and whether each scale is assessing a distinct construct" (Aldridge & Fraser, 2008, p. 22). To obtain a factor structure and to examine it against the *a priori* 6-scale structure of the learning environment scales in the questionnaire, principal axis factor analysis with varimax rotation as well as Kaiser normalisation was applied.

From the original 48 items in the learning environment part of the questionnaire, factor analysis confirmed an optimal structure comprising 44 items in the same 6-factor structure for Investigation, Task Orientation, Collaboration, Differentiation, Computer Usage and Formative Assessment.

A factor loading of at least 0.40 on its own scale and less than 0.40 on each of the other five scales were the criteria used for keeping any item. All items that were retained had a factor loading of at least 0.40 on their *a priori* scale, ranging from 0.42 to 0.79, and less than 0.40 on all other scales. Items 2 and 4 from Investigation scale and Items 25 and 29 from Differentiation scale were removed as they did not load 0.40 or above on their own or on any other scale. The rest of the 44 items in the questionnaire had a loading of at least 0.40 on their *a priori* scale and no other scale (see Table 4.1). The percentage of variance ranged from 3.66% to 23.72% for the six scales, with the total variance being 54.01%.

Because each scale had an eigenvalue greater than 1 (see the bottom of Table 4.1), all the scales were extracted based on Kaiser's criterion (Kaiser, 1960). The results of the factor analysis, shown in Table 4.1, strongly underpin the validity of the learning environment scales in the questionnaire for the group of secondary school gifted students in Singapore.

Table 4.1: Factor Analysis Results for Learning Environment Questionnaire

Item No	Factor Loadings					
	Investigation	Task Orientation	Collaboration	Differentiation	Computer Usage	Formative Assessment
Investigation 1	0.64					
Investigation 3	0.73					
Investigation 5	0.71					
Investigation 6	0.69					
Investigation 7	0.75					
Investigation 8	0.55					
Task Orientation 9		0.57				
Task Orientation 10		0.60				
Task Orientation 11		0.55				
Task Orientation 12		0.51				
Task Orientation 13		0.58				
Task Orientation 14		0.64				
Task Orientation 15		0.60				
Task Orientation 16		0.58				
Collaboration 17			0.55			
Collaboration 18			0.54			
Collaboration 19			0.60			
Collaboration 20			0.66			
Collaboration 21			0.69			
Collaboration 22			0.77			
Collaboration 23			0.73			
Collaboration 24			0.61			
Differentiation 26				0.42		
Differentiation 27				0.59		
Differentiation 28				0.75		
Differentiation 30				0.72		
Differentiation 31				0.69		
Differentiation 32				0.76		
Computer Usage 33					0.58	
Computer Usage 34					0.52	
Computer Usage 35					0.56	
Computer Usage 36					0.63	
Computer Usage 37					0.63	
Computer Usage 38					0.61	
Computer Usage 39					0.63	
Computer Usage 40					0.61	
Formative Assessment 41						0.45
Formative Assessment 42						0.70
Formative Assessment 43						0.57
Formative Assessment 44						0.79
Formative Assessment 45						0.75
Formative Assessment 46						0.70
Formative Assessment 47						0.73
Formative Assessment 48						0.69
% Variance	5.19	5.99	10.62	4.83	3.66	23.72
Eigenvalue	2.49	2.87	5.10	2.13	1.76	11.39

N = 722 students in 27 classes.
Principal axis factoring with varimax rotation and Kaiser normalisation.
Factor loadings less than 0.40 have been omitted from the table.
Items 2, 4, 25 and 29 were removed from the learning environment scales.

The questionnaire used in my study included 5 scales from the TROFLEI, which has been validated in numerous studies undertaken in Australia (Aldridge & Fraser, 2008; Aldridge et al., 2004; Aldridge et al., 2012), New Zealand (Koul et al., 2011), Turkey (Cakir, 2011; Welch et al., 2012) and United States of America (Earle & Fraser, 2016; Welch et al., 2012).

The current study revealed similar validity results comparable to the above studies involving the TROFLEI. The COLES, a new instrument developed by Aldridge et al. (2012), contains both the WIHIC scales and scales linked to assessing student learning. The COLES has been validated in high schools across Western Australia and the results obtained for the Formative Assessment scale for my sample were comparable to those in this study.

Next, the internal structure of the 32-item, four-scale version of the attitude questionnaire was analysed to establish if the items in each scale were measuring the same construct and whether each scale was determining a distinct construct. Again, principal axis factor analysis with varimax rotation and Kaiser normalisation was applied to obtain a factor structure for the questionnaire and to examine against the *a priori* 4-scale structure of the questionnaire.

A factor loading of at least 0.40 on its own scale and less than 0.40 on each of the other three scales were the criteria used in retaining any item. Table 4.2 shows the factor loadings for the attitude questionnaire. All items were retained because they had factor loading of at least 0.40 on their own scale and no other scales. The factor loadings ranged from 0.48 to 0.85.

The first scale in the attitude questionnaire, Attitudes towards Computers was taken from the AEQ which was adapted by Aldridge and Fraser (2008) from earlier versions of the CAS designed by Loyd and Gressard (1984) and Newhouse (2001). This refined scale was used in a study at Sevenoaks Senior College with Year 11 and 12 students (Aldridge & Fraser, 2008). In my study, all the 8 items were retained and the factor loadings ranged from 0.50 to 0.85, which are similar to those obtained in the study at Sevenoaks Senior College.

The factor loading for the next three scales, Task Value, Self-Efficacy and Self-Regulation taken from the SALES (Velayutham et al., 2012), were compared

Table 4.2: Factor Analysis Results for Attitude Scales

Item No	Factor Loading			
	Attitude towards Computers	Task Value	Self-Efficacy	Self-Regulation
Attitude towards Computers 49	0.50			
Attitude towards Computers 50	0.84			
Attitude towards Computers 51	0.80			
Attitude towards Computers 52	0.64			
Attitude towards Computers 53	0.81			
Attitude towards Computers 54	0.85			
Attitude towards Computers 55	0.64			
Attitude towards Computers 56	0.71			
Task Value 57		0.62		
Task Value 58		0.56		
Task Value 59		0.48		
Task Value 60		0.76		
Task Value 61		0.73		
Task Value 62		0.70		
Task Value 63		0.53		
Task Value 64		0.67		
Self- Efficacy 65			0.60	
Self- Efficacy 66			0.70	
Self- Efficacy 67			0.71	
Self- Efficacy 68			0.64	
Self- Efficacy 69			0.66	
Self- Efficacy 70			0.70	
Self- Efficacy 71			0.68	
Self- Efficacy 72			0.65	
Self- Regulation 73				0.67
Self- Regulation 74				0.70
Self- Regulation 75				0.55
Self- Regulation 76				0.62
Self- Regulation 77				0.59
Self- Regulation 78				0.68
Self- Regulation 79				0.65
Self- Regulation 80				0.70
% Variance	30.00	6.50	14.36	6.94
Eigenvalue	9.60	2.08	4.60	2.22

N = 722 students in 27 classes.
Principal axis factoring with varimax rotation and Kaiser normalisation.
Factor loadings less than 0.40 have been omitted from the table.

with validity results of other studies. The results in this study were analogous with studies in Australia (Rogers, 2013; Velayutham et al., 2012) and the United States of America (Koren, 2013) for which all the retained items loaded above 0.40 on their respective factor and less than 0.40 on any other factor.

The percentage of variance ranged from 6.50% to 30.00% for the four attitude scales, with the total variance accounted for by the 32 items in four scales in the attitude questionnaire being 57.80%. Each scale had an eigenvalue greater than 1. The factor structure, high cumulative variance and eigenvalues shown in Table 4.2 firmly support the validity of the attitude questionnaire for the sample of secondary school students in Singapore.

4.2.2 Internal Consistency Reliability, Discriminant Validity and Ability to Differentiate Between Classes

Items 2, 4, 25 and 29 were removed from the questionnaire because they did not load 0.40 or above on their own or on any other scale. The rest of the 44 learning environment items and all the 32 attitude items were retained when validating this refined 76-item learning environment and attitude questionnaire, the following three statistical analyses were carried out: the Cronbach alpha reliability coefficient, a convenient discriminant validity index and the ability to differentiate between classrooms using Analysis of Variance (ANOVA).

For the descriptive statistics reported in Table 4.3, the individual student and the class mean were used as the units of analysis. When using a questionnaire, it is important that the items in a scale measure the same dimension. If this is the case, then the scale is said to have internal consistency. The internal consistency of each learning environment and attitude scale was estimated by calculating Cronbach's alpha coefficient. The values were high for every learning environment and attitude scale and ranged from 0.83 to 0.90 using the individual student as unit of analysis and from 0.90 to 0.97 using class mean as the unit of analysis (Table 4.3).

"Discriminant validity assesses the extent to which a scale is unique in the dimension that it covers" and the "mean correlation of a scale with other scales" (Aldridge & Fraser, 2008, p. 28) was used as a convenient index to attest that each of the scales in each questionnaire measures a separate and distinct dimension from that of other scales. The discriminant validity indicated by mean correlations in Table 4.3 shows that most scales were fairly distinct in the dimension that each assessed. For the learning environment scales, the mean correlation of a scale with other scales varied from 0.29 to 0.46 using the individual student as unit of analysis and from 0.50 to 0.71 using class mean as the unit of analysis. For the attitude scales, the mean correlation of a scale with other scales varied from 0.34 to 0.57 using the individual student as unit of analysis and 0.35 to 0.69 using class mean as the unit of analysis. This suggests

Table 4.3: Item Mean, Item Standard Deviation, Internal Consistency Reliability (Cronbach Alpha Coefficient), Discriminant Validity (Mean Correlation) for All Scales and Ability to Differentiate Between Classrooms (ANOVA Result) for Learning Environment Scales

Scale	No of Item	Unit of Analysis	Mean	SD	Alpha Reliability	Mean Correlation	ANOVA Eta²
Learning Environment							
Investigation	6	Individual	3.22	0.68	0.87	0.44	0.10**
		Class	3.23	0.22	0.96	0.71	
Task Orientation	8	Individual	4.03	0.57	0.86	0.46	0.10**
		Class	4.04	0.18	0.92	0.70	
Collaboration	8	Individual	4.08	0.56	0.87	0.41	0.07**
		Class	4.08	0.15	0.90	0.61	
Differentiation	6	Individual	2.28	0.74	0.83	0.29	0.08**
		Class	2.29	0.23	0.91	0.50	
Computer Usage	8	Individual	3.02	0.75	0.84	0.41	0.30**
		Class	3.02	0.42	0.96	0.61	
Formative Assessment	8	Individual	3.96	0.62	0.90	0.42	0.11**
		Class	4.00	0.21	0.97	0.62	
Attitudes							
Attitudes towards Computers	8	Individual	3.19	0.79	0.90	0.34	
		Class	3.18	0.23	0.94	0.35	
Task Value	8	Individual	3.94	0.55	0.88	0.53	
		Class	3.95	0.18	0.95	0.62	
Self-Efficacy	8	Individual	3.44	0.66	0.90	0.57	
		Class	3.45	0.20	0.95	0.69	
Self-Regulation	8	Individual	3.84	0.59	0.88	0.54	
		Class	3.85	0.20	0.93	0.69	

$^{**}p<0.01$ $N=722$
Eta² reflects the percentage of variance for each scale attribute to class membership. It is the ratio of 'between' to `total' sums of squares

that the scales were positively related to one another and that there was a stronger relationship between the scales when class mean is used as the unit of analysis. Although some mean correlations for raw scores were relatively high, overall, the discriminant validity was acceptable. Furthermore, the findings of the factor analyses reinforced the point that factor scores on each scale of the instrument were a relatively distinct aspect.

Analysis of Variance (ANOVA) was used to check the ability of each scale to differentiate between the perceptions of the students in different classrooms. The independent variable was class membership (*N*=27). The eta^2 statistics from ANOVA was calculated for each scale to indicate the proportion of variance explained by class membership. (The ability to differentiate between classrooms is not relevant for the attitudes scales.)

The ANOVA findings shown in Table 4.3 confirm that all learning environment scales differentiated significantly between students in different classes. Students in the same class perceived the learning environment in a comparatively identical manner, while the mean perceptions of students in different classes differed. The eta^2 statistics for learning environment scales in the questionnaire ranged from 0.07 to 0.30.

The statistical analyses presented in Table 4.3, together with the factor analyses in Table 4.1 and 4.2, suggest that the learning environment and attitude questionnaire was sound instruments for determining students' perceptions of the learning environment and their attitudes among secondary school gifted female students in Singapore. Table 4.4 shows how the reliability values found in my study compare favourably with those obtained from other studies.

4.3 Differences Between Students' Attitudes and Perceptions of Learning Environment in Technology-based and Regular Classrooms

In the previous section (4.2), the questionnaire used in this study were investigated to see if they were credible and dependable for measuring students' perceptions of the learning environment and their attitudes when administered among secondary school gifted female students in Singapore. In this section,

Table 4.4: Comparing Sample Size and Internal Consistency Reliabilities (Cronbach Alpha Coefficients) in Previous Studies and Current Study for Learning Environment and Attitude Scales

Reference(s)	Country(ies)	Sample Size	Cronbach's alpha coefficient									
			Investigation	Task Orientation	Collaboration	Differentiation	Computer Usage	Formative Assessment	Attitudes towards Computers	Task Value	Self-Efficacy	Self-Regulation
Current Study	Singapore	772	0.87	0.86	0.87	0.83	0.84	0.90	0.90	0.88	0.90	0.88
Aldridge et al. (2004)	Australia	1249	0.88	0.93	0.91	0.77	0.88					
Aldridge & Fraser (2008)	Australia	2317	0.92	0.88	0.91	0.85	0.88		0.83			
Aldridge et al. (2012)	Australia	2043		0.87	0.90	0.82		0.92				
Bell & Aldridge (2014)	Australia	2042 (2008)		0.84	0.88	0.74		0.90				
		4467 (2009)		0.82	0.87	0.70		0.88				
		3836 (2010)		0.83	0.83	0.80		0.86				
Dorman et al. (2006)	Australia	4146	0.94	0.89	0.92	0.82	0.88					
Dorman (2009)	Australia	4407	0.94	0.89	0.92	0.82	0.88		0.84			
Earle & Fraser (2016)	USA	914	0.92	0.90	0.87	0.83	0.89					
Gupta & Fisher (2012)	India	705	0.82	0.78	0.82	0.68						
Koul et al. (2011)	New Zealand	1027	0.90	0.88	0.88	0.75	0.84		0.80			
Velayutham et al.(2011)	Australia	1360								0.92	0.92	0.91

Unit of Analysis: Individual

differences between technology-based science classrooms and regular science classrooms, with regards to students' attitudes and perceptions of classroom learning environment, are examined to address the second research question:

Research Question 2

For gifted female students in Singapore, do scores on attitude and learning environment scales vary between technology-based and regular science classrooms?

Table 4.5 and Figure 4.1 show each scale's average item mean, which is the scale mean divided by the number of items in that scale, when the individual student was used as the unit of analysis. The item mean was somewhat higher for all the ten scales for technology-based science classes than regular science classes. For example, the average item mean was 3.34 for the technology-based science classes and 3.10 for the regular classes for the Investigation scale. The differences in average item means for the rest of the scales are shown in the Figure 4.1. The average item mean for Computer Usage in technology-based classrooms was 3.51 and in regular classrooms was 2.78. This is anticipated because the students in technology-based classrooms are involved in a teaching and learning process in the classroom using laptop computers.

It is noteworthy from Figure 4.1 that the average item means are above 3.00 for all eight scales except Differentiation regardless of the type of classroom. This suggests that, regardless of classroom type, students perceived the features of learning environment as often being suitable for the gifted in terms of Investigation, Task Orientation, Collaboration and Formative Assessment. Also students in both types of classrooms tended to agree with statements about Attitudes towards Computers, Task Value, Self-efficacy and Self-regulation.

To investigate the statistical significance of differences between technology-based and regular classrooms in terms of learning environment and student attitudes, multivariate analysis of variance (MANOVA) was conducted. The six learning environment scales and four attitude scales constituted the set of dependent variables, whereas instructional method (technology-based vs regular classes) constituted the independent variable. "Because the multivariate test using

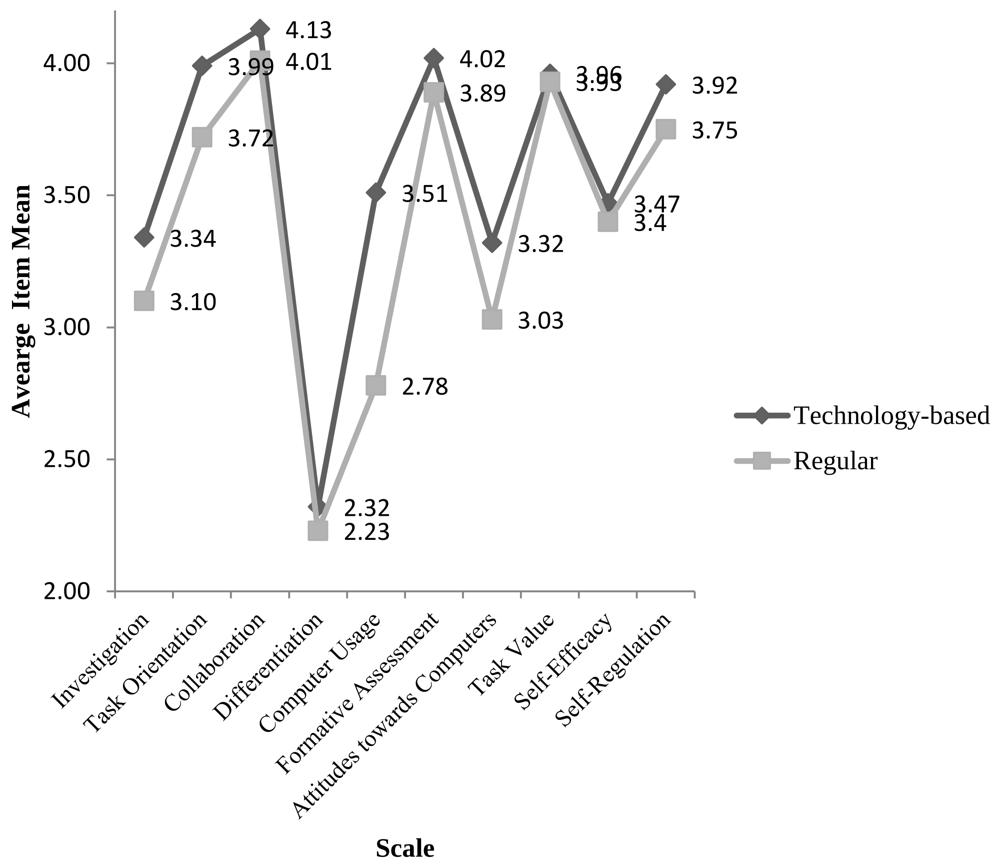

Figure 4.1 Average Item Mean Scores for Learning Environment and Attitude Scales for Technology-based and Regular Classes.

Wilks' lambda criterion revealed statistically-significant between-group differences for the set of dependent variables" (Lightburn & Fraser, 2007, p. 162) as a whole, the results of the univariate ANOVA for each individual dependent variable were interpreted separately and recorded in Table 4.5. (Initially conducting MANOVA provided protection against Type 1 errors because the significance of between-group differences for individual learning environment and attitude scales was only considered after significant between-group differences had been found for the whole set of 10 dependent variables.)

Based on the results in Table 4.5, differences between the two type of classrooms were statistically significant for seven scales, namely, Investigation, Task Orientation, Collaboration, Computer Usage, Formative Assessment, Attitudes towards Computers and Self-Regulation with the individual student as the unit of analysis. Students in technology-based science classrooms perceived more investigation, task orientation, collaboration, computer usage, and formative assessment than students in regular science classrooms. When the unit of analysis is the class mean, scores were significantly different between technology-based science classes and regular classes for Investigation, Task Orientation, Computer Usage and Attitudes towards Computers, with technology-based classes having higher means.

Differences between technology-based and regular science classrooms were not statistically significant for either unit of analysis for three scales: Differentiation, Task Value and Self-Efficacy. Students in both types of classrooms were comparable in their perceptions of differentiation and attitudes related to task value and self-efficacy.

To further investigate the differences between technology-based science classes and regular science classes, effect sizes were calculated. An "effect size is simply an objective and (usually) standardised measure of the magnitude of an observed effect" (Field, 2009, p. 56) and is independent of sample size. Cohen's *d* is a common measure of effect size and it can be calculated by finding the difference between the means and dividing it by the pooled standard deviation (Cohen, 1988). "The pooled standard deviation is found as the root mean square of the two standard deviations" (Cohen, 1988, p. 44). Table 4.5 reports the effect sizes for the technology-based and regular science classes for each learning environment and attitudinal scale.

According to Cohen (1992), an effect size of ≤ 0.20 can be considered small, an effect size of 0.5 is moderate and an effect size of 0.80 or greater is a large effect size.

When the unit of analysis is the student and for those scales for which differences between technology-based and regular classes were statistically significant (Investigation, Task Orientation, Collaboration, Computer Usage, Formative Assessment, Attitudes towards Computers and Self-regulation), effect sizes were 0.36, 0.40, 0.22, 1.09, 0.27, 0.37 and 0.31 standard deviations, respectively. Based on Cohen's criteria, these effect sizes are small/moderate for all scales except for Computer Usage for which the effect size is large.

With the class mean as the unit of analysis and for scales for which differences between technology-based and regular classes were statistically significant (Investigation, Task Orientation, Computer Usage and Attitudes towards Computers), effect sizes were 1.17, 1.42, 3.15 and 1.66 standard deviations, respectively. This suggests that between-group differences in perceptions of Investigation, Task Orientation and Computer Usage in the classroom learning environment and in Attitudes towards Computers were large based on Cohen's criteria.

The results are of educational importance and reflect the teachers' efforts in meeting the outcomes of the one-student one-laptop programme which, as described in Chapter 1, was introduced in 2012 in the school where this study was carried out. Every student brings a laptop computer to school and instruction in class involves the use of the technology. In the science classrooms, inquiry-based learning is highly encouraged and, with the introduction of computers, the school aims to provide a learning environment that promotes digital literacy, self-directed and collaborative learning, critical and creative thinking skills, research skills, problem-solving skills, differentiation and feedback on learning.

The effectiveness of the new one-student one-laptop initiative in promoting the development of the desired attitudes in gifted classrooms is evident based on the findings of this study. In Singapore, Crescent Girls' School was one of the first schools to introduce ICT in teaching. All of its 1300 student use tablet PCs to learn essential ICT skills. The school introduced the m-Learning@Crescent programme in 2004 and established pedagogically-strong use of ICT for

Table 4.5: Average Item Mean, Average Item Standard Deviation and Difference Between Technology-Based and Regular Science Classes (ANOVA Result and Effect Size) for Each Perceived Learning Environment and Attitude Scale for Two Units of Analysis

Instrument	Scale	Unit of Analysis	Item Mean		Item SD		Difference	
			Technology-based	Regular	Technology-based	Regular	*F*	Effect Size (Cohen's *d*)
TROFLEI	Investigation	Individual	3.34	3.10	0.67	0.67	22.94**	0.36
		Class	3.34	3.11	0.17	0.22	8.82**	1.17
	Task Orientation	Individual	4.14	3.92	0.56	0.55	28.84**	0.40
		Class	4.13	3.93	0.15	0.14	13.18**	1.42
	Collaboration	Individual	4.13	4.01	0.56	0.55	8.24**	0.22
		Class	4.14	4.03	0.12	0.15	4.00	0.78
	Differentiation	Individual	2.32	2.23	0.78	0.70	2.62	0.12
		Class	2.33	2.24	0.17	0.27	0.96	0.35
	Computer Usage	Individual	3.36	2.64	0.58	0.73	217.56**	1.09
		Class	3.36	2.66	0.12	0.29	71.57**	3.15
COLES	Formative Assessment	Individual	4.02	3.89	0.58	0.66	8.24**	0.27
		Class	4.03	3.92	0.17	0.24	2.07	0.53
AEQ	Attitudes towards Computers	Individual	3.32	3.03	0.77	0.79	26.11**	0.37
		Class	3.32	3.03	0.18	0.17	19.45**	1.66
SALES	Task Value	Individual	3.96	3.93	0.55	0.54	0.38	0.06
		Class	3.96	3.94	0.19	0.17	0.06	0.11
	Self-Efficacy	Individual	3.47	3.40	0.66	0.66	2.25	0.11
		Class	3.48	3.42	0.19	0.22	0.50	0.29
	Self-Regulation	Individual	3.92	3.75	0.53	0.64	15.60**	0.31
		Class	3.91	3.77	0.17	0.21	3.92	0.73

**$p<0.01$ N=722 in 27 classes
Cohen's *d* is calculated by dividing the difference between the means by the root mean square of the two standard deviations.

teaching and learning that received positive feedback from educators, both locally and globally. In 2007, the MOE identified the school as one of the five conferred as FutureSchools@Singapore and the South Zone Centre of Excellence for ICT.

In another study conducted in Australia, Stolarchuk and Fisher (2001), using laptops had little effect on students' perceptions of science classroom environment. Laptop students' perceptions were found to be more positively associated with students' attitudinal outcomes than with their cognitive achievement outcomes. Qualitative data revealed that, in the first few years of using laptops in science classrooms, students learned more about computers than science.

4.4 Associations Between Learning Environment and Student Attitudes

In Section 4.2, evidence was reported to support the validity and reliability of the instruments for measuring students' perceptions of their learning environment and their attitudes when administered among secondary school gifted female students in Singapore. In Section 4.3, differences between technology-based science classrooms and regular science classrooms in terms of students' attitudes and perceptions of classroom learning environments were reported. In this section, the third research question is addressed:

Research Question 3

Are there associations between students' perceptions of classroom learning environments and their attitudes among gifted female students in a secondary school in Singapore?

Relationships between the learning environment and student attitudes in technology-based and regular science classrooms were determined by calculating simple correlations (r), standardised regression coefficients (β) and multiple correlations (R) as reported in Table 4.6. Simple correlation is a good way to assess the direction and the strength of the bivariate relationship between an independent variable and a dependent variable. A quick scan of the *r* values in Table 4.6 shows that all attitude scales were positively correlated with learning environment scales for technology-based classes and for nearly all environment scales for regular classes. The three nonsignificant correlations for regular classes were between Attitudes towards Computers and Task Orientation and Formative Assessment and between Task Value and Differentiation.

The multiple correlations in Table 4.6 reveal that the six learning environment scales had a positive influence on each of the four attitudinal outcomes in both technology-based and regular science classrooms. The multiple correlations were statistically significant ($p<0.01$) with the individual student as the unit of analysis. In technology-based science classrooms, the *R* value between the six learning environment scales and attitudes was 0.46 for Attitudes towards Computers, 0.64 for Task Value, 0.65 for Self-Efficacy and 0.72 for Self-Regulation. In the regular classrooms, the *R* value between the six learning environment scales and attitudes was 0.52 for Attitudes towards Computers, 0.59 for Task Value, 0.59 for Self-Efficacy and 0.62 for Self-Regulation. In technology-based science classrooms, the strength of the multiple correlation was slightly greater between learning environment and the attitudinal outcomes of Task Value, Self-Efficacy and Self-Regulation than in regular science classrooms. Conversely, in regular science classrooms, the strength of the multiple correlation was slightly greater between learning environment scales and Attitudes towards Computers.

The standardised regression coefficients (β) in Table 4.6 indicate the individual influence that each learning environment scale had on an attitude scale when the other independent variables were mutually controlled. It represents the number of standard deviations by which an outcome changes as a result of one standard deviation change in the independent variable. Standardised regression coefficients revealed which of the six learning environment scales contributed significantly ($p<0.05$) to the variance in the attitudinal outcomes when the other five environment scales were controlled.

Table 4.6: Associations Between Learning Environment and Attitudes in Technology-Based and Regular Classrooms in Terms of Simple Correlations (*r*), Standardised Regression Coefficients (β) and Multiple Correlations (*R*)

Scale	Attitudes towards Computers				Task Value				Self-Efficacy				Self-Regulation			
	Technology-based		Regular		Technology-based		Regular		Technology-based		Regular		Technology-based		Regular	
	r	β	*r*	β	*r*	β	*R*	β	*r*	β	*R*	β	*r*	β	*r*	β
Investigation	0.15**	0.00	0.15**	0.01	0.42**	0.19**	0.24**	0.04	0.39**	0.09	0.26**	0.03	0.39**	0.08	0.29**	0.05
Task Orientation	0.12*	-0.02	0.01	-0.13*	0.53**	0.29**	0.49**	0.26**	0.53**	0.41**	0.54**	0.40**	0.67**	0.56**	0.60**	0.50**
Collaboration	0.17**	0.02	0.21**	0.16**	0.28**	-0.05	0.27**	0.01	0.22**	-0.13	0.22**	-0.06	0.31**	-0.10*	0.28**	0.03
Differentiation	0.13*	-0.03	0.26**	0.04	0.16**	0.12	0.09	0.08	0.29**	0.26**	0.13*	0.07	0.12*	0.12**	0.13*	0.04
Computer Usage	0.44**	0.45**	0.49**	0.46**	0.16**	-0.06	0.12*	-0.05	0.25**	0.02	0.26**	0.11*	0.17**	-0.04	0.26**	0.11*
Formative Assessment	0.13**	0.04	0.07	-0.01	0.53**	0.32**	0.54**	0.39**	0.48**	0.25**	0.46**	0.23**	0.56**	0.23**	0.41**	0.08
Multiple Correlation (*R*)		0.46**		0.52**		0.64**		0.59**		0.65**		0.59**		0.72**		0.62**

*$p < 0.05$, **$p < 0.01$ N=722 Unit of analysis: Individual

The regression coefficients in Table 4.6 indicate that Investigation was a significant independent predictor of Task Value in technology-based science classrooms. Task Orientation was a significant independent predictor of Task Value, Self-Efficacy and Self-Regulation in both technology-based and regular science classrooms. Task Orientation was a negative independent predictor of Attitudes towards Computers in regular science classrooms which means that, when task orientation increased, attitudes towards computers decreased by 0.13 standard deviations.

Collaboration was a significant independent predictor of Attitudes towards Computers in regular science classrooms. Collaboration was a negative independent predictor of Self-Regulation in technology-based science classes, which means that, when collaboration increased, self-regulation decreased by 0.10 standard deviations.

Differentiation was a significant independent predictor of Self-Efficacy and Self-Regulation in technology-based science classrooms.

Computer Usage was a significant independent predictor of Attitudes towards Computers in technology-based science classrooms and a significant independent predictor of Attitudes towards Computers, Self-Efficacy and Self-Regulation in regular science classrooms.

Formative Assessment was a significant independent predictor of Task Value, Self-Efficacy and Self-Regulation in technology-based science classrooms, and of Task Value and Self-Efficacy in regular science classrooms.

Task Orientation emerged as having the strongest associations with Task Value, Self-Efficacy and Self-Regulation attitudinal scales and this finding is similar to other studies involving learning environment and the SALES attitude scales (Koren, 2013; Velayutham et al., 2011). The next strongest link was seen between Formative Assessment and the same three attitudinal scales of Task Value, Self-Efficacy and Self-Regulation. This finding is unique in that this is the first empirical study that has established a significant relationship between the

Formative Assessment scale and attitudes scales from the SALES. My research is distinctive because it attempted to compare associations between learning environment and student attitudes in technology-based and regular science classrooms. The results in this study confirmed that there were negligible differences between technology-based and regular classes in the strength and direction of associations between the learning environment and student attitudes. In other words, introducing computers into the learning processes in the classroom neither enhanced nor reduced the effect of the learning environment on student attitudes. This finding could be an important consideration for educational institutions when implementing technology in the classroom. However, because this is the first study in gifted classrooms, future research should focus on this area before findings can be generalised to populations in other settings.

Every simple correlation was positive, establishing that relationships between learning environment and student attitudes were positive. The statistically significant multiple correlations also confirmed the impact of the learning environment on student attitudes and that these results can be generalised for the population in this study. Nearly all significant regression coefficients were also positive except between Attitudes towards Computers and Task Orientation in regular science classrooms and between Self-regulation and Collaboration in technology-based science classrooms. These results are consistent with past studies conducted in different countries that investigated associations between the learning environment and attitudes in Australia (Aldridge & Fraser, 2008; Aldridge et al., 2012; Dorman & Fraser, 2009; Stolarchuk & Fisher, 2001; Velayutham & Aldridge, 2013), India (Gupta & Fisher, 2012), New Zealand (Koul et al., 2011) and Singapore (Chionh & Fraser, 2009; Chua, Wong, & Chen, 2011; Quek et al., 2005; Wong & Fraser, 1996).

4.5 Summary of the Chapter

This chapter reported results for analyses of the data that were collected for this research. The overarching aim of this research was to investigate whether introducing technology in the classroom was achieving some of its intended goals. To address this purpose, the three main objectives in this study were to investigate: (1) whether the questionnaire assessing learning environment and attitudes are valid and reliable when administered among secondary school gifted female students in Singapore; (2) differences between technology-based science classrooms and regular science classrooms in terms of students' attitudes and perceptions of classroom learning environment; and (3) associations between the classroom learning environment and student attitudes.

The data in this study were derived from 722 students in a school for gifted girls in Singapore. Using a questionnaire, responses were obtained from 379 students from 14 technology-based science classrooms and 343 students from 13 regular science classrooms. The data were statistically analysed using the IBM SPSS Statistics software in order to answer the objectives stated above.

The first objective was to investigate whether the questionnaire used in this study to assess the learning environment and student attitudes were valid and reliable when used with gifted female students in a secondary school in Singapore. Separate factor analyses were carried out for the 48-item six-scale version of the learning environment questionnaire and 32-item four-scale version of the attitude questionnaire.

Principal axis factor analysis with varimax rotation and Kaiser normalisation was employed to obtain a factor structure for each questionnaire. The criteria for the retention of any item were a factor loading of at least 0.40 on its own scale and less than 0.40 on each of the other scales. Four items were removed from the learning environment scales because they did not load 0.40 or above on their own or on any other scale, but the rest of the 44 items were retained. All 32 items in the attitude scales were retained. The percentage of variance varied from 3.66% to 23.72% with a total variance of 54.01% for the six learning environment scales and from 6.50% to 30.00% with a total variance of 57.80% for the four attitude scales. Each scale had an eigenvalue greater than 1. The results of the factor analyses strongly supported the structure or factorial validity of the learning environment and attitude questionnaire for the sample of gifted girls in the secondary school in Singapore.

The internal consistency of each learning environment and attitude scale was estimated by calculating Cronbach's alpha coefficient. For the learning environment scales, the values were high and ranged from 0.83 to 0.90 using the individual student as unit of analysis and from 0.90 to 0.97 using the class mean as the unit of analysis. The alpha values for the attitude scales were also high and ranged from 0.88 to 0.90 using the individual student as unit of analysis and from 0.93 to 0.95 using the class mean as the unit of analysis.

The mean correlation of a scale with the other learning environment scales varied from 0.29 to 0.46 using the individual student as unit of analysis and 0.50 to 0.71 using the class mean as the unit of analysis. The mean correlation of a scale with the other attitude scales varied from 0.34 to 0.57 using the individual student as unit of analysis and 0.35 to 0.69 using the class mean as the unit of analysis. This showed that discriminant validity was acceptable and confirmed that each scale evaluates a relatively distinct aspect. Furthermore, the factor analyses attested to the independence of factor scores.

The use of ANOVA for each scale, with class membership as the independent variable, suggested that all learning environment scales differentiated significantly between students in different classes, with the eta^2 statistic ranging from 0.07 to 0.30 for different scales. Overall, analyses suggested that the learning environment and attitude questionnaire was valid and reliable for assessing gifted girls' perceptions of the learning environment and their attitudes at a secondary school in Singapore.

The second objective was to investigate differences between technology-based science classrooms and regular science classrooms in terms of students' attitudes and perceptions of classroom learning environment. For this, the average item mean and average item standard deviation for each of the scales in the questionnaire were calculated. The statistical significance of differences between

groups was ascertained using MANOVA and ANOVAs, whereas the magnitude of between-group differences was calculated using Cohen's *d* effect size. Differences between the two types of classrooms were statistically significant for seven scales, namely, Investigation, Task Orientation, Collaboration, Computer Usage, Formative Assessment, Attitudes towards Computers and Self-Regulation with the individual student unit of analysis. When the unit of analysis was the class mean, differences between technology-based and regular science classrooms were statistically significant for the four scales of Investigation, Task Orientation, Computer Usage and Attitudes towards Computers. Differences between technology-based and regular science classrooms were not statistically significant for the three scales of Differentiation, Task Value and Self-Efficacy.
The significant differences between technology-based and regular science classes were further illuminated by calculating effect sizes using Cohen's *d*, which expresses a between-group difference in standard deviation units. According to Cohen's (1992) criteria, effect sizes for differences between technology-based science classrooms and regular science classrooms in perceptions of Collaboration, Differentiation, Formative Assessment, Self-Efficacy and Self-Regulation were moderate, while differences for Investigation, Task Orientation, Computer Usage and Attitudes towards Computers were large. The effect size for Computer Usage was 3.15 standard deviations with class as the unit of analysis, which is not surprising because students in technology-based science classrooms used computers in the classroom more than students in regular science classrooms.

The third and final objective was to investigate associations between the classroom learning environment and student attitudes. The data were separately analysed for technology-based and regular science classrooms. Associations between the classroom learning environment and student attitudes were determined using simple correlation and multiple regression analyses using the individual as the unit of analysis.

All attitude scales were positively and significantly correlated with learning environment scales for technology-based classes and for nearly all environment scales for regular classes. The three nonsignificant correlations for regular classes were between Attitudes towards Computers and Task Orientation and Formative Assessment and between Task Value and Differentiation.

The multiple correlations revealed that the six learning environment scales had a positive and statistically significant association with the four attitudinal outcomes in both technology-based and regular science classrooms. Overall, the strength and direction of association between learning environment and the attitudinal outcomes were similar in technology-based science classrooms and regular science classrooms.

Chapter 5, the concluding chapter of this thesis, summarises and further discusses the findings in this research and its contributions to practice and the fields of learning environments and gifted education. Also, limitations of this study are discussed and recommendations for future research are proposed.

Chapter 5
DISCUSSION AND CONCLUSION

5.1 Introduction

The underlying aim of my research was to assess the effect of technology by investigating differences between technology-based science classrooms and regular classrooms in terms of students' attitudes and perceptions of classroom learning environment. Also, associations between the learning environment and student attitudes in both types of classrooms were investigated.

The learning environments of technology and regular science classrooms were assessed using fives scales from the TROFLEI developed by Dorman et al. (2006) and one scale from the COLES developed by Aldridge et al. (2012). Students' attitudes were assessed using one scale from the AEQ designed by Aldridge and Fraser (2008) and three scales from the SALES questionnaire (Velayutham et al., 2011).

The participants in this study were high-ability female students attending a private secondary school in Singapore. They were among the top 1% to 3% scorers in Singapore's national examination for primary-school leavers before gaining admission into the school. There were a total of 722 participants in this research and their ages ranged from 14 to 16 years. The perceptions and attitudes of 379 Grade 9 students from the technology-based classrooms were compared with those of 343 Grade 10 students from the regular science classrooms.

Section 5.2 of this chapter summarises the findings of this research as reported in Chapter 4. Section 5.3 discusses the significance of this study for the field of learning environments and its implications for educational institutions. Section 5.4 considers my study's limitations, whereas Section 5.5 proposes recommendations for future research in this area. Finally Section 5.6 provides concluding comments.

5.2 Summary of Results

The sub-sections that follow provide a brief account of the results for each research question in the current study.

5.2.1 Results for Research Question 1

Research Question 1:

Are learning environment scales based on the TROFLEI and COLES and attitude scales based on the AEQ and SALES valid and reliable when used with gifted female students in a secondary school in Singapore?

Principal axis factor analysis with varimax rotation and Kaiser normalisation was applied to obtain a factor structure and to check it against the *a priori* 6-scale structure of the learning environment scales in the questionnaire. From the original 48 items in the learning environment questionnaire, factor analysis confirmed a structure comprising 44 items in the same 6-factor structure consisting of Investigation, Task Orientation, Collaboration, Differentiation, Computer Usage and Formative Assessment.

"A factor loading of at least 0.40 on its own scale and less than 0.40 on each of the other" (Aldridge & Fraser, 2008, p. 24) five scales were the criteria used for retaining any item. All of the 44 learning environment items retained had a factor loading of at least 0.40 on their *a priori* scale, ranging from 0.42 to 0.79, and less than 0.40 on all other scales. Items 2 and 4 from the Investigation scale and Items 25 and 29 from the Differentiation scale were removed because they did not load 0.40 or above on their own or on any other scales, suggesting that these four items might not be measuring the intended constructs The percentage of variance varied from 3.66% to 23.72% for the six scales, with the total variance accounted for being 54.01%. Because each scale had an eigenvalue greater than 1, all the scales extracted satisfied Kaiser's (1960) criterion.

The learning environment questionnaire used in my study included 5 scales from the TROFLEI, which has been validated in numerous studies undertaken in Australia (Aldridge et al., 2004; Aldridge & Fraser, 2008), New Zealand (Koul et al., 2011), Turkey (Cakir, 2011; Welch et al., 2012) and United States of America (Earle & Fraser, 2016; Welch et al., 2012). The current study revealed similar validity results comparable to the above studies involving the TROFLEI.

The COLES, a relatively new instrument developed by Aldridge et al. (2012), contains both the WIHIC scales and scales related to the assessment of student learning. The COLES has been validated in high schools (Aldridge et al., 2012; Bell & Aldridge, 2014) across Western Australia and the results obtained for the Formative Assessment scale for my sample were comparable to those in previous studies.

Again, principal axis factor analysis with varimax rotation and Kaiser normalisation was used to extract a factor structure for the 32-item, four-scale version of the attitude questionnaire and to check against its *a priori* 4-scale structure. All items were retained because they had a factor loading of at least 0.40 on their own scale and less than 0.40 on all the other scales.

The first scale in the attitude questionnaire, Attitudes towards Computers, was taken from the AEQ which was adapted by Aldridge and Fraser (2008) from earlier versions of the CAS designed by Loyd and Gressard (1984) and Newhouse (2001). This modified scale was used in a study at Sevenoaks Senior College with Year 11 and 12 students (Aldridge & Fraser, 2008). In my study, all the 8 items were retained and the factor loadings ranged from 0.50 to 0.85, which are similar to those obtained in the study at Sevenoaks Senior College.

The factor loadings for the next three scales, Task Value, Self-Efficacy and Self-Regulation taken from the SALES (Velayutham et al., 2012), were comparable to those in studies in Australia (Rogers, 2013; Velayutham et al., 2012) and the United States of America (Koren, 2013) for which all the retained items loaded above 0.40 on their respective factor and less than 0.40 on any other factor.

The percentage of variance varied from 6.50% to 30.00% for the four attitude scales, with the total variance accounted for by the 32 items in four scales in the attitude questionnaire being 57.80%. Each scale had an eigenvalue greater than 1. The factor structure, high cumulative variance and eigenvalues firmly supported the validity of the attitude questionnaire for my sample of secondary-school students in Singapore.

When the internal consistency of each scale in the learning environment and attitude questionnaire was calculated using the Cronbach's alpha coefficient, values were high and ranged from 0.83 to 0.90 using the individual student as unit of analysis and from 0.90 to 0.97 using class mean as the unit of analysis. The reliability coefficients for the learning environment and attitude scales used in my study were similar to those in previous studies by Aldridge et al. (2004), Aldridge and Fraser (2008), Aldridge et al. (2012), Bell and Aldridge (2014), Velayutham et al. (2011) and Welch, Cakir, Peterson and Ray (2014).

The discriminant validity, which was indicated by the "mean correlation of a scale with the other scales" (Aldridge & Fraser, 2008, p. 28), showed that most scales were fairly distinct in the dimension that each assessed. For the six learning environment scales, the mean correlation of a scale with the other scales varied from 0.29 to 0.46 using the individual student as unit of analysis and from 0.50 to 0.71 using the class mean as the unit of analysis. For the four attitude scales, the mean correlation of a scale with the other scales varied from 0.34 to 0.57 using the individual student as unit of analysis and from 0.35 to 0.69 using the class mean as the unit of analysis. This suggests that the scales were positively related to one another and that there was a stronger relationship between the scales when class mean was used as the unit of analysis. Although some mean correlations for raw scores were relatively high, overall, the discriminant validity was acceptable. Furthermore, the findings of the factor analyses reinforced that factor scores on each scale of the instrument evaluated a relatively distinct aspect.

Analysis of variance (ANOVA) was used to assess the ability of each learning environment scale to "differentiate between the perceptions of the students in different classrooms" (Aldridge & Fraser, 2008, p. 24). The ability to differentiate between classrooms is not relevant for the attitudes scales. The independent variable was class membership (*N*=27). The eta^2 value calculated for each scale indicated the proportion of variance explained by class membership. The ANOVA results shown in Table 4.3 confirm that all learning environment scales differentiated significantly between students in different classes. Students within the same class perceived the environment in a relatively similar manner, while the mean perceptions of students in different classes varied. The eta^2 statistics for learning environment scales in the questionnaire ranged from 0.07 to 0.30, which are similar values to those in past studies (Dorman et al., 2006; Koul et al., 2011)

The statistical analyses summarised above are presented in Table 4.3, together with the factor analyses in Table 4.1 and 4.2, confirm that the learning environment and attitude questionnaire was sound after removal of items 2, 4, 25 and 26, for determining students' perceptions of the learning environment and their attitudes when administered among secondary school gifted female students in Singapore.

5.2.2 Results for Research Question 2

Research Question 2

For gifted female students in Singapore, do scores on attitude and learning environment scales vary between technology-based and regular science classrooms?

The effectiveness of using technology was investigated by comparing the psychosocial learning environment and attitudes of gifted girls in technology-based science classrooms and regular science classrooms. The item mean was somewhat higher for all the ten scales for technology-based science classes than regular science classes. In order to ascertain the statistical significance of differences between technology-based and regular classrooms in terms of learning environment and student attitudes, multivariate analysis of variance (MANOVA) was conducted. The six learning environment scales and four attitude scales constituted the set of dependent variables, whereas instructional method (technology-based vs regular classes) constituted the independent variable. "Because the multivariate test using Wilks' lambda criteria revealed statistically-significant between-group differences for the set of dependent variables" (Lightburn & Fraser, 2007, p. 162) as a whole, the results of the univariate ANOVA for each individual dependent variable were interpreted separately.

Differences between the two types of classrooms were statistically significant for seven scales, namely, Investigation, Task Orientation, Collaboration, Computer Usage, Formative Assessment, Attitudes towards Computers and Self-Regulation with the individual student unit of analysis. Students in the technology-based science classrooms perceived more investigation, task orientation, collaboration, computer usage, and formative assessment than students in regular science classrooms. The results suggest that the use of ICT in teaching did not have a positive impact on students' learning.

When the class mean was used as the unit of analysis, scores were significantly different between technology-based science classes and regular classes for Investigation, Task Orientation, Computer Usage and Attitudes towards Computers, with technology-based classes having higher means. Differences between technology-based and regular science classrooms were not statistically significant for either unit of analysis for three scales: Differentiation, Task Value and Self-Efficacy. Students in both types of classrooms were comparable in their perceptions of differentiation and attitudes related to task value and self-efficacy.

To further investigate the differences between technology-based science classes and regular science classes, effect sizes were calculated. Cohen's *d* effect size expresses a difference between means in standard deviation units. According to

Cohen (1992), an effect size of ≤0.20 can be considered small, an effect size of 0.5 is moderate and of 0.80 or greater is a large effect size. With the student as the unit of analysis and for those scales for which differences between technology-based and regular classes were statistically significant (Investigation, Task Orientation, Collaboration, Computer Usage, Formative Assessment, Attitudes towards Computers and Self-regulation), effect sizes were 0.36, 0.40, 0.22, 1.09, 0.27, 0.37 and 0.31 standard deviations, respectively. Based on Cohen's criteria, these effect sizes are small/moderate for all scales except for Computer Usage for which the effect size was large.

5.2.3 Results for Research Question 3

Research Question 3

Are there associations between students' perceptions of classroom learning environments and their attitudes among gifted female students in a secondary school in Singapore?

Associations between the classroom learning environment and student attitudes in technology-based and regular science classrooms were investigated by calculating simple correlations, standardised regression coefficients and multiple correlations. The data were separately analysed for technology-based and regular science classrooms. All attitude scales were positively and significantly correlated with learning environment scales for technology-based classes and for nearly all environment scales for regular classes. The three nonsignificant correlations for regular classes were between Attitudes towards Computers and Task Orientation and Formative Assessment and between Task Value and Differentiation.

The multiple correlations revealed that the six learning environment scales had a positive and statistically significant multivariate association with the four attitudinal outcomes in both technology-based and regular science classrooms. However, the strength and direction of associations between the learning environment and student attitudes were similar for technology-based and regular classes.

My finding that Task Orientation had the strongest associations with the Task Value, Self-Efficacy and Self-Regulation attitudinal scales is similar to other studies involving learning environment and the SALES attitude scales (Koren, 2013; Velayutham et al., 2011). The next strongest link was between Formative Assessment and the same three attitudinal scales of Task Value, Self-Efficacy and Self-Regulation. Every simple correlation was positive, establishing that relationships between learning environment and student attitudes were positive. The statistically significant multiple correlations further confirmed the impact of the learning environment on student attitudes. Nearly all significant regression coefficients were also positive except between Attitudes towards Computers and Task Orientation in regular science classrooms and between Self-regulation and Collaboration in technology-based science classrooms. These results are consistent with past studies conducted in different countries that investigated associations between learning environment and attitudes in Australia (Aldridge & Fraser, 2008; Aldridge et al., 2012; Dorman & Fraser, 2009; Stolarchuk & Fisher, 2001; Velayutham & Aldridge, 2013), India (Gupta & Fisher, 2012), New Zealand (Koul et al., 2011) and Singapore (Chionh & Fraser, 2009; Chua et al., 2011; Quek et al., 2005; Wong & Fraser, 1996).

5.3 Significance and Implications

A review of the literature on learning environment research indicates that the majority of past studies focused on Western contexts. Therefore past findings and recommendations might not be applicable in the Asian context because of cultural differences. However, with some noteworthy attempts to extend this field of research in Singapore in recent years, there are now about 13 learning environment studies reported (Chionh & Fraser, 2009; Chua et al., 2011; Goh & Fraser, 1998; Goh & Fraser, 2016; Goh et al., 1995; Khoo & Fraser, 2008; Koh & Fraser, 2014; Lim, 2013; Pang, 1999; Peer & Fraser, 2015; Quek et al., 2005; Teh

& Fraser, 1994; Wong & Fraser, 1995). Therefore, this study contributes to the body of knowledge on learning environments in Singapore's educational settings.

This was the first study in Singapore that employed learning environment scales from the TROFLEI and COLES together with attitude scales from the AEQ and SALES. As part of my research, these learning environment and attitude questionnaire was validated for use in Singapore for assessing students' perceptions of their classroom environment and attitudes towards computers, task value, self-efficacy and self-regulation. These instruments can be used in the future in Singapore in gathering students' feedback for teachers as a basis for making improvements to the classroom learning environment and subsequently achieving particular student outcomes.

Many studies have shown the need to differentiate and modify the curriculum and instruction (Maker & Nelson, 1996) to meet the intellectual needs of gifted students based on educators' points of view. My learning environment study is also a significant contribution to gifted education research in Singapore. MOE funding for schools with gifted learners is proportionately greater because the students need to be developed to realise their potential and to be leaders of the country in the future. Among the 13 previous learning environment studies in Singapore, only one focused on secondary gifted students. Though this is the second documented study focusing on gifted secondary females in Singapore, my sample was larger and is unique because it was the first study to compare gifted females in technology-based science and regular science classroom.

The results are of educational importance because they reflect the teachers' efforts in meeting the outcomes of the one-student one-laptop initiative which was introduced in 2012 in the school where this study was carried out. Every student brings a laptop computer to school and instruction in class involves the use of the technology. In science classrooms, inquiry-based learning is highly encouraged and, with the introduction of computers, the school aims to provide a learning environment that promotes digital literacy, self-directed and collaborative learning, critical and creative thinking skills, research skills, problem-solving skills, differentiation and feedback on learning. The findings of this study are significant because they provide evidence about the effectiveness of the new one-student one-laptop initiative in promoting a positive learning environment and desirable attitudes in gifted classrooms.

Numerous past studies have revealed positive links between the learning environment and students attitudes (Fraser, 2014). In this study, Task Orientation emerged as having the strongest associations with the Task Value, Self-Efficacy and Self-Regulation attitudinal scales. The next strongest link was between Formative Assessment and the same three attitudinal scales of Task Value, Self-Efficacy and Self-Regulation. These findings have practical implications for teachers wishing to enhance students' task value, self-efficacy and self-regulation by emphasising task orientation and formative assessment in their classroom environments. My research was the first study to establish a significant relationship between the Formative Assessment scale and attitudes scales from the SALES.

My research is distinctive because it attempted to compare associations between learning environment and student attitudes in technology-based and regular science classrooms. This study supported that there was no major difference between technology-based and regular classes in the strength and direction of associations between the learning environments and student attitudes. In other words, introducing computers into the learning processes in the classroom neither enhanced nor reduced the effect of learning environment on student attitudes. Though this finding could be important for educational institutions when implementing technology in the classroom, one must not conclude that the use of laptops is not a worthwhile investment. This is because this study was the first documented study in gifted classrooms, future research should focus on this area before findings can be generalised to other settings or populations.

5.4 Limitations

My study, like all research, had limitations. However, every effort was made to minimize their effects. The student sample in this study consisted of 722 students, with 379 students enrolled in Grade 9 technology-based science classes and 343 students enrolled in Grade 10 in regular science classrooms. The students were female high-ability learners who attended a single-sex private school in Singapore. The age of student respondents ranged from 14 to 16 years. One limitation is that students in technology-based classes were at the grade 10 level, but students in regular/traditional classes were at the grade 9 level. Also, the present study did not attempt to include female high-ability students from other all-girls schools because the type of school could have been a confounding variable. Because the sample came from one single-sex school for females, caution should be exercised when applying the findings to other all-girls schools, all-boys schools, co-educational schools and broader groups.

Another limitation in this study was that the ethnic distribution of the students who formed the sample was relatively homogenous. Approximately 80% were Chinese and the other 20% of students comprised Indians, Malays, Koreans, Vietnamese and other ethnic groups. The generalisability of results obtained therefore could be influenced by this ethnic mix.

The present study was limited because it used students' perceptions of the learning environment and attitudes as the only criteria for evaluating the effectiveness of the technology-based classrooms. Dependent variables such as achievement and other valuable student outcomes were excluded. Future studies could also investigate associations between the learning environment and achievement or other cognitive outcomes in technology-based classrooms.

The findings from the present study were based on science classrooms. Therefore, it is not clear if the findings are generalisable to other subjects such as humanities, mathematics and languages. Future research could be extended to include students' perceptions and attitudes in other school subjects such as the languages, mathematics, humanities and aesthetics.

Finally, this study was based on quantitative data derived from students' response to the learning environment and attitude questionnaire. As noted by Tobin and Fraser (1998), a mixed-methods study involving both qualitative and quantitative methods could have provided richer data regarding students' experiences and motivations in the classrooms, allowed triangulation of different data sources, and enhanced the validity of the research findings.

To obtain a factor structure for the learning environment and attitude questionnaire, principal axis factor analysis with varimax rotation and Kaiser normalisation was conducted. The percentage of variance, total variance extracted with each factor and the eigenvalue for each scale were also calculated. Internal consistency reliability, discriminant validity and ability to differentiate between classes were also calculated. To investigate differences between technology-based science classrooms and regular science classrooms in terms of students' attitudes and perceptions, MANOVA/ANOVAs and effect sizes were used. To investigate the associations between students' perceptions of their classroom environments and attitudes, simple correlation and multiple regression analyses were also conducted. Although these methods of statistical analysis were both suitable and adequate for my study, a possible limitation is that I did not also employ alternative methods of analysis such as confirmatory factor analysis, multilevel analysis or structural equation modeling (SEM).

5.5 Recommendations for Future Research

For researchers to assess the benefits of technology-based classrooms with greater confidence, future research could involve a larger, more-diverse and representative sample of students across different types of schools. These studies could focus on gifted males, non-gifted males and female students in primary and secondary schools and higher-education institutions. Larger samples would improve the statistical power of analyses and more-diverse samples would enhance the generalisability of findings.

There is a dearth of research on learning environment in gifted classrooms. Therefore, research on learning environments should focus more frequently on the experiences of gifted students in different schools and the extent to which the goals of the gifted curriculum are achieved in the classroom.

While there have been many studies of the learning environment in secondary-school settings, there have been fewer studies in primary and higher-education institutions. Future research should focus on investigating the learning environments at these educational levels.

Most past research has focused on Western contexts and so its findings and recommendations might not be applicable in the Asian context because of cultural differences. Although there have been some noteworthy attempt to extend the field of research in Asia in recent years, more studies could be undertaken in Asia to see if there are differences in the classroom experiences of students from different cultural backgrounds.

Past studies have identified gender differences in how students' perceive their learning environments. The present study could be extended to investigate gender differences in students' reactions to technology-based classrooms. Female students' attitudes to science and their propensity to underachieve in science or avoid science courses and careers provide another potential research area that can be explored.

Further studies in this area could involve both quantitative and qualitative methods to provide a better understanding of students' perceptions of the learning environment, as recommended by Tobin and Fraser (1998). Mixed-methods research, combining quantitative data from questionnaires with qualitative interviews or observations, could provide richer information with wider scope and breadth on the topic under study. Future studies could also involve teachers' perceptions of the learning environment so that any differences between students' and teachers' perceptions could be addressed in attempts to improve student learning and attitudes.

5.6 Concluding Comments

The main objective of my research was to evaluate the effectiveness of using technology in science classrooms among female gifted students in a Singapore school, using learning environment and attitude criteria. I also investigated the validity and reliability of a learning environment and an attitude questionnaire and associations between the classroom learning environment and student attitudes. Overall, the results of this study suggested that the learning environment and attitude questionnaire was valid and reliable and that the learning environment scales differentiated significantly between students in different classes. Statistically significant differences between technology-based and regular classes emerged for the learning environment scales of Investigation, Task Orientation, Collaboration, Computer Usage and Formative Assessment, and attitude scales of Attitudes towards Computers and Self-regulation (with effect sizes of 0.36, 0.40, 0.22, 1.09, 0.27, 0.37 and 0.31 standard deviations, respectively).

This study also confirmed positive associations between the learning environment and student attitudes. However, there was negligible difference between technology-based and regular classes in the strength and direction of associations between the learning environments and student attitudes.

One main contribution of the present study is that it cross-validated learning environment scales from the TROFLEI and COLES and attitude scales from the AEQ and SALES, and confirmed their suitability when used with gifted female students at a secondary school in Singapore. This provides further evidence to educational researchers and practitioners about the validity and reliability of the instruments that previously have been mainly used in Western countries such as Australia and the USA.

Another significant contribution of this study is that, though it is the second documented study focusing on gifted secondary females in Singapore, my sample was larger and my research was unique as the first study in the country that compared gifted females in technology-based science and regular science classroom. The results of my study are of educational importance because they provide evidence about the effectiveness of technology usage in enhancing the classroom environment and promoting positive student attitudes in gifted classrooms.

The study also revealed similar associations between learning environment and student attitudes in technology-based and regular science classrooms. However, this was the first study that has established a significant relationship between the Formative Assessment scale and attitudes scales from the SALES. This finding has a practical implication for classroom teachers seeking to improve the learning environments of students.

Finally, it is hoped that this study will encourage other educational researchers and practitioners to undertake investigations to contribute to the limited body of knowledge on the effectiveness of using technology in classrooms. It is also hoped that this study helps to convince teachers that students' perception can be used as data to inform their own classroom practice.

REFERENCES

Adamski, A., Fraser, B. J., & Peiro, M. (2013). Parental involvement in schooling, classroom environment and student outcomes. *Learning Environments Research, 16*(3), 315-328.

Afari, E., Aldridge, J. M., Fraser, B. J., & Khine, M. S. (2013). Students' perception of the learning environment and attitudes in game-based mathematics classrooms. *Learning Environments Research, 16*, 131-150.

Aldridge, J. M., Dorman, J. P., & Fraser, B. J. (2004). Use of multi-trait–multi-method modelling to validate actual and preferred forms of the Technology-Rich Outcomes-Focused Learning Inventory (TROFLEI). *Australian Journal of Educational and Developmental Psychology, 4,* 110-125.

Aldridge, J. M., & Fraser, B. J. (2000). A cross-cultural study of classroom learning environments in Australia and Taiwan. *Learning Environments Research, 3*, 101-134.

Aldridge, J. M., & Fraser, B. J. (2008). *Outcomes-focused learning environments: Determinants and effects*. Rotterdam, The Netherlands: Sense Publishers.

Aldridge, J. M., Fraser, B. J., Bell, L., & Dorman, J. (2012). Using a new learning environment questionnaire for reflection in teacher action research. *Journal of Science Teacher Education, 23*(3), 259-290.

Aldridge, J. M., Fraser, B. J., & Huang, I. T. C. (1999). Investigating classroom environments in Taiwan and Australia with multiple research methods. *Journal of Educational Research, 93*, 48-62.

Aldridge, J. M., Fraser, B. J., & Ntuli, S. (2009). Utilising learning environment assessments to improve teaching practices among in-service teachers undertaking a distance education programme. *South African Journal of Education, 29*, 147-170.

Aldridge, J. M., Fraser, B. J., & Sebela, M. P. (2004). Using teacher action research to promote constructivist learning environments in South Africa. *South African Journal of Education, 24*, 245-253.

Aldridge, J. M., Fraser, B. J., Taylor, P. C., & Chen, C. C. (2000). Constructivist learning environments in a cross-national study in Taiwan and Australia. *International Journal of Science Education, 22*, 37-55.

Aldridge, J. M., Laugksh, R. C., & Fraser, B. J. (2006). School level environment and outcomes-based education in South Africa. *Learning Environments Research, 9*, 123-147.

Allen, D., & Fraser, B. J. (2007). Parent and student perceptions of classroom learning environment and its association with student outcomes. *Learning Environments Research, 10*, 67-82.

Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Educational Psychology, 84*, 261-271.

Ary, D., Jacobs, L. C., Razavieh, A., & Sorensen, C. (2006). *Introduction to research in education* (7th ed.). Belmont, CA: Thomson Wadsworth.

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist, 44*, 1175-1184.

Bandura, A. (1986). *Social foundations of thought and action*: *A social cognitive theory*. Englewood Cliffs, NJ: Prentice Hall.

Bandura, A. (1989). Human agency in social cognitive theory. *American Psychologist, 44*, 1175-1184.

Baron, R. A., & Byrne, D. E. (1977). *Social psychology: Understanding human interaction*. Boston: Allyn and Bacon.

Bell, L. M., & Aldridge, J. M. (2014). *Student voice, teacher action research and classroom improvement*. Rotterdam, The Netherlands: Sense Publishers.

Bernreuter, R. G., Miles, C. C., Tinker, M. A., & Young, K. (1942). *Studies in personality*. New York: McGraw-Hill Book Company.

Beverly, J., & Farenga, S. (1999). Informal science experience, attitudes, future interest in science, and gender of high-ability students: An exploratory study. *School Science and Mathematics, 99*(8), 431-437.

Binet, A., & Simon, T. (1905). Méthodes nouvelles pour le diagnostic du niveaux [New methods for diagnosing abnormal intellectual levels]. *L'année Psychologique, 11*, 191–336.

Boekaerts, M., & Cascallar, E. (2006). How far have we moved toward the integration of theory and practice in self-regulation? *Educational Psychology Review, 18*, 199-210.

Brookhart, S. M., Walsh, J. M., & Zientarski, W. A. (2006). The dynamics of motivation and effort for classroom assessments in middle school science and social studies. *Applied Measurement in Education, 19*, 151-184.

Burden, R., & Fraser, B. J. (1993). Use of classroom environment assessments in school psychology. *Psychology in the Schools, 30*, 232-240.

Burg, B. (1992). Gifted education in Israel. *Roeper Review, 14*, 217-221.

Bybee, R. W. (1994). *Reforming science education: Social perspectives and personal reflections*. New York: Teachers College Press.

Cakir, M. (2011). Validity and reliability of the Turkish form of Technology-Rich Outcome-Focused Learning Environment Inventory. *Kuram Uygulamada Egit. Bilim, 11*(4), 1959-1963.

Caleon, I. S., & Subramaniam, R. (2008). Attitudes towards science of intellectually gifted and mainstream upper primary students in Singapore. *Journal of Research in Science Teaching, 45*(8), 940-954.

Callahan, C. M. (2012). *Fundamentals of gifted education: Considering multiple perspectives*. Hoboken: Taylor and Francis.

Chionh, Y. H., & Fraser, B. J. (2009). Classroom environment, achievement, attitudes and self-esteem in geography and mathematics in Singapore. *International Research in Geographical and Environmental Education, 18*, 29-44.

Chua, S. L., Wong, A. F. L., & Chen, V. D. (2011). The nature of Chinese language classroom learning environments in Singapore secondary schools. *Learning Environments Research, 14*, 75-90.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*, 155-159.

Cohn, S. T., & Fraser, B. J. (2016). Effectiveness of student response systems in terms of learning environment, attitudes and achievement. *Learning Environments Research, 19*, 153-167

Colangelo, N., & Davis, G. A. (2003). *Handbook of gifted education* (3rd ed.). Boston: Allyn & Bacon.

Creton, H., Hermans, J., & Wubbels, T. (1990). Improving interpersonal teacher behaviour in the classroom: A systems communication perspective. *South Pacific Journal of Teacher Education, 18*, 85-94.

Davis, G. A., & Rimm, S. B. (2004). *Education of the gifted and talented*. Boston: Pearson Education.

den Brok, P., Fisher, D., Rickards, T., & Bull, E. (2006). Californian science students' perception of their classroom learning environments. *Educational Research and Evaluation, 12*, 3-25.

Dhindsa, H. S., & Fraser, B. J. (2004). Culturally-sensitive factors in teacher trainees' learning environments. *Learning Environments Research, 7*, 165-181.

Diezmann, C. M., & Watters, J. J. (2001). The collaboration of mathematically gifted students on challenging tasks. *Journal for the Education of the Gifted, 25*(1), 7-31.

Docker, J. G., Fraser, B. J., & Fisher, D. L. (1989). Differences in the psychosocial work environment of different types of schools. *Journal of Research in Childhood Education, 4*, 5-17.

Dorman, J. P. (2003). Cross-national validation of the What Is Happening In this Class? (WIHIC) questionnaire using confirmatory factor analysis. *Learning Environments Research, 6*, 231-245.

Dorman, J. P. (2008). Use of multitrait─multimethod modelling to validate actual and preferred forms of the What Is Happening In this Class? questionnaire. *Learning Environments Research, 11*, 179-197.

Dorman, J. P. (2009). Association between psychosocial environment and outcomes in technology-rich classrooms in Australian Secondary Schools. *Research Education, 82(1)*, 69-84. Dorman, J. P., Aldridge, J. M., & Fraser, B. J. (2006). Using students' assessment of classroom environment to develop a typology of secondary school classrooms. *International Education Journal, 7*, 909-915.

Dorman, J. P., & Fraser, B. J. (1996). Teachers' perceptions of school environment in Australian Catholic and government secondary schools. *International Studies in Educational Administration, 24*(1), 78-87.

Dorman, J. P., & Fraser, B. J. (2009). Psychosocial environment and affective outcomes in technology-rich classrooms. *Social Psychology of Education, 12*, 77-99.

Dorman, J. P., Fraser, B. J., & McRobbie, C. J. (1997). Relationship between school-level and classroom-level environment in secondary schools. *Journal of Educational Administration, 35*, 74-91.

Doyle, W. (1979). Classroom tasks and students' abilities. In P.L. Peterson & H.L. Walberg (Eds.), *Research on teaching: Concepts, findings, and implications* (pp. 97-121). Berkeley, CA: McCutchan.

Duschl, R. A., & Waxman, H. C. (1991). Influencing the learning environment of student teaching. In B. J. Fraser & H. J. Walberg (Eds.), *Educational environments: Evaluation, antecedents and consequences* (pp. 255-270). London: Pergamon.

Dweck, C. S. (1986). Motivational process affecting learning. *American Psychologist, 41*, 1040-1048.

Earle, J. E., & Fraser, B. J. (2016, Online first). Evaluating online resources in terms of classroom environment and student attitudes in middle-grades mathematics. *Learning Environments Research*.

Eccles, L. (2007). *Gender differences in teacher-student interactions, attitudes and achievement in middle school science* (Unpublished PhD thesis). Curtin University, Western Australia.

Ellett, C. D., Loup, K. S., & Chauvin, S. W. (1989). *System for Teaching and Learning Assessment and Review (STAR): Annotated guide to teaching and learning*. Baton Rouge, LA: Louisiana Teaching Internship and Teacher Evaluation Projects, College of Education, Louisiana State University.

Ellett, C. D., & Walberg, H. J. (1979). Principals' competency, environment, and outcomes. In H. J. Walberg (Ed.), *Educational environments and effects: Evaluation, policy, and productivity* (pp. 140-164). Berkeley, CA: McCutchan.

Ferguson, P. D., & Fraser, B. J. (1998). Changes in learning environment during the transition from primary to secondary school. *Learning Environments Research, 1*(3), 369-383.

Field, A. P. (2009). *Discovering statistics using SPSS* (3rd ed.). London: Sage.

Fisher, D. L., & Cresswell, J. (1998). Actual and ideal principal interpersonal behaviour. *Learning Environments Research, 1*, 231-247.

Fisher, D. L., & Fraser, B. J. (1981). Validity and Use of My Class Inventory. *Science Education, 65*, 145-156.

Fisher, D. L., & Fraser, B. J. (1983a). A comparison of actual and preferred classroom environments as perceived by science teachers and students. *Journal of Research in Science Teaching, 20*, 55-61.

Fisher, D. L., & Fraser, B. J. (1983b). Use of WES to assess science teachers' perception of school environment. *European Journal of Science Education, 5*, 231-233.

Fisher, D. L., & Fraser, B. J. (1991). School climate and teacher professional development. *South Pacific Journal of Teacher Education, 19*(1), 17-32.

Fisher, D. L., Fraser, B. J., & Bassett, J. (1995). Using a classroom environment instrument in an early childhood classroom. *Australian Journal of Early Childhood, 20*(3), 10-15.

Fisher, D. L., Henderson, D., & Fraser, B. J. (1995). Interpersonal behaviour in senior high school biology classes. *Research in Science Education, 25*, 125-133.

Fisher, D. L., Henderson, D., & Fraser, B. J. (1997). Laboratory environments and student outcomes in senior high school biology. *American Biology Teacher, 59*, 214-219.

Fisher, D. L., & Waldrip, B. G. (1997). Assessing culturally sensitive factors in the learning environment of science classrooms. *Research in Science Education, 27*, 41-49.

Fisher, T. H. (1973). The development of an attitude survey for junior high science. *School Science and Mathematics, 73*, 647-652.

Fraser, B. J. (1978). Development of a test of science-related attitudes. *Science Education, 62*, 509-515.

Fraser, B. J. (1981). *Test of Science Related Attitudes (TOSRA)*. Melbourne, Australia: Australian Council for Educational Research.

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

Fraser, B. J. (1990). *Individualised Classroom Environment Questionnaire*. Melbourne, Australia: Australian Council for Educational Research.

Fraser, B. J. (1991). Two decades of classroom environment research. In B.J. Fraser & H. J. Walberg (Eds.), *Educational environments: Evaluation antecedents and consequences* (pp. 3-7). London: Pergamon.

Fraser, B. J. (1993). Incorporating classroom and school environment ideas into teacher education programmes. In T. A. Simpson (Ed.), *Teacher educators' annual handbook* (pp. 135-152). Brisbane, Australia: Queensland University of Technology.

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

Fraser, B. J. (1997). NARST's expansion, internationalization and cross-nationalization (1996 Annual Meeting Presidential Address). *NARST News, 40*(1), 3-4.

Fraser, B. J. (1998a). Classroom environment instruments: Development, validity and applications. *Learning Environments Research, 1*, 7-33.

Fraser, B. J. (1998b). Science learning environments: Assessment, effects and determinants. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 527-564). Dordrecht, The Netherlands: Kluwer.

Fraser, B. J. (1999). 'Grain sizes' in learning environments research: Combining qualitative and quantitative methods. In H.C. Waxman & H. J. Walberg (Eds.), *New directions for teaching practice and research* (pp. 285-296). Berkeley, CA: McCutchan.

Fraser, B. J. (2001). Twenty thousand hours: Editor's introduction. *Learning Environments Research, 4*, 1-5.

Fraser, B. J. (2007). Classroom learning environments. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 103-124). London: Lawrence Erlbaum Associates.

Fraser, B. J. (2012). Classroom learning environments: Retrospect, context and prospect. In B. J. Fraser, K. G. Tobin, C.J. McRobbie (Eds.), *The second international handbook for science education research* (pp. 1191-1239). New York: Springer.

Fraser, B. J. (2014). Classroom learning environments: Historical and contemporary perspectives. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education volume II* (pp. 104-119). New York: Routledge.

Fraser, B. J., Aldridge, J. M., & Adolphe, F. S. G. (2010). A cross-national study of secondary science classroom environments in Australia and Indonesia. *Research in Science Education, 40*, 551-571.

Fraser, B. J., Aldridge, J. M., & Soerjaningsih. (2010). Instructor-student interpersonal interaction and student outcomes at the university level in Indonesia. *The Open Education Journal, 3*, 32-44.

Fraser, B. J., Anderson, G. J., & Walberg, H. J. (1982). *Assessment of learning environments: Manual for Learning Environment Inventory (LEI) and My Class Inventory (MCI)* (third version). Perth, Australia: Western Australian Institute of Technology.

Fraser, B. J., & Butts, W. L. (1982). Relationship between perceived levels of classroom individualization and science-related attitudes. *Journal of Research in Science Teaching, 19*, 143-154.

Fraser, B. J., & Deer, C. E. (1983). Improving classrooms through the use of information about learning environment. *Curriculum Perspectives, 3*(2), 41-46.

Fraser, B. J., Docker, J. G., & Fisher, D. L. (1988). Assessing and improving school climate. *Evaluation and Research in Education, 2*(3), 109-122.

Fraser, B. J., & Fisher, D. L. (1983a). Development and validation of short forms of some instruments for measuring student perceptions of actual and preferred classroom learning environment. *Science Education, 67*, 115-131.

Fraser, B. J., & Fisher, D. L. (1983b). Student achievement as a function of person-environment fit: A regression surface analysis. *British Journal of Educational Psychology, 53*, 89-99.

Fraser, B. J., & Fisher, D. L. (1986). Using short forms of classroom climate instruments to assess and improve classroom psychosocial environment. *Journal of Research in Science Education, 5,* 387-413.

Fraser, B. J., Fisher, D. L., & McRobbie, C. J. (1996, April). *Development, validation, and use of personal and class forms of a new classroom environment instrument*. Paper presented at the presented at the annual meeting of the American Educational Research Association, New York.

Fraser, B. J., Giddings, G. J., & McRobbie, C. J. (1995). Evolution and validation of a personal form of an instrument for assessing science laboratory classroom environments. *Journal of Research in Science Teaching, 32,* 399-422.

Fraser, B. J., & Kahle, J. B. (2007). Classroom, home and peer environment influences on student outcomes in science and mathematics: An analysis of systemic reform data. *International Journal of Science Education, 29,* 1891-1909.

Fraser, B. J., & Lee, S. S. U. (2009). Science laboratory classroom environments in Korean high schools. *Learning Environments Research, 12*, 67-84.

Fraser, B. J., & McRobbie, C. J. (1995). Science laboratory classroom environments at schools and universities. *Educational Research and Evaluation, 1*, 289-317.

Fraser, B. J., McRobbie, C. J., & Giddings, G. J. (1993). Development and cross-national validation of a laboratory classroom environment instrument for senior high school science. *Science Education, 77*, 1-24.

Fraser, B. J., & O'Brien, P. (1985). Student and teacher perceptions of the environment of elementary-school classrooms. *Elementary School Journal, 85*, 567-580.

Fraser, B. J., & Rentoul, A. J. (1982). Relationship between school-level and classroom-level environment. *Alberta Journal of Educational Research, 28*, 212-225.

Fraser, B. J., & Tobin, K. (1991). Combining qualitative and quantitative methods in classroom environment research. In B. J. Fraser & H. J. Walberg (Eds.), *Educational environments: Evaluation, antecedents and consequences* (pp. 271-292). London: Pergamon.

Fraser, B. J., & Treagust, D. F. (1986). Validity and the use of an instrument for assessing classroom psychosocial environment in higher education. *Higher Education, 15*, 37-57.

Fraser, B. J., Treagust, D. F., Williamson, J. C., & Tobin, K. G. (1987). Validation and application of the College & University Classroom Environment Inventory (CUCEI). In B. J. Fraser (Ed.), *The study of learning environments* (pp. 17-30). Perth, Western Australia: Curtin University of Technology.

Fraser, B. J., & Walberg, H. J. (Eds.). (1991). *Educational environments: Evaluation, antecedents and consequences*. London, UK: Pergamon.

Fraser, B. J., & Walberg, H. J. (2005). Research on teacher-student relationships and learning environments: Context, retrospect and prospect. *International Journal of Educational Research, 43*, 103-109.

Fraser, B. J., Walberg, H. J., Welch, W. W., & Hattie, J. A. (1987). Syntheses of educational productivity research. *International Journal of Educational Research*, *11*, 145-252.

Fraser, B. J., Welch, W. W., & Walberg, H. J. (1986). Using secondary analysis of national assessment data to identify predictors of junior high school students' outcomes. *Alberta Journal of Educational Research, 32*, 37-50.

Gall, M. D., Gall, J. P., & Borg, W. R. (2003). *Educational research: An introduction* (7th ed.). Boston: Allyn and Bacon.

Galton, F. (1869). *Hereditary genius: An inquiry into its laws and consequences*. New York: Appleton.

Gardner, P. L. (1975). Attitudes to science: A review. *Studies in Science Education*, *2*, 1-41.

Getzels, J. W., & Thelen, H. A. (1960). The classroom group as a unique social system. In N. B. Henry (Ed.), *The dynamics of instructional groups: Socio-psychological aspects of teaching and learning* (Fifty-Ninth Yearbook of National Society for Study of Education, Part 2) (pp. 53-82). Chicago: University of Chicago Press.

Goh, S. C., & Fraser, B. J. (1996). Validation of an elementary school version of the Questionnaire on Teacher Interaction. *Psychological Reports*, *79*, 512-522.

Goh, S. C., & Fraser, B. J. (1998). Teacher interpersonal behaviour, classroom environment and student outcomes in primary mathematics in Singapore. *Learning Environments Research, 1*, 199-229.

Goh, S. C., & Khine, M. S. (Eds.). (2002). *Studies in educational learning environments: An international perspective*. Singapore: World Scientific.

Goh, S. C., Young, D. J., & Fraser, B. J. (1995). Psychosocial climate and student outcomes in elementary mathematics classrooms: A multilevel analysis. *The Journal of Experimental Education, 64*, 29-40.

Goh, S. F., & Fraser, B. J. (2016). The learning environment in Singapore primary science classrooms: The ideal and the real. In K. Wallace (Ed.), *Learning environments: Emerging theories, applications and future directions* (pp. 125-141). New York: Nova Publishers.

Gross, M. (1999). Inequity in equity: The paradox of gifted education in Australia. *Australian Journal of Education, 43*(1), 87-103.

Gupta, A., & Fisher, D. (2012). Technology-supported learning environments in science classrooms in India. *Learning Environments Research, 15*(2), 195-216.

Haertel, G. D., Walberg, H. J., & Haertel, E. W. (1981). Socio-psychological environments and learning: A quantitative synthesis. *British Educational Research Journal*, *7*, 27-36.

Halpin, A. W., & Croft, D. B. (1963). *Organisational climate of schools*. Chicago, IL: Midwest Administration Center: University of Chicago.

Hasan, A., & Fraser, B. J. (2015). Effectiveness of teaching strategies for engaging adults who experienced childhood difficulties in learning mathematics. *Learning Environments Research, 18*, 1-13.

Helding, K., & Fraser, B. J. (2013). Effectiveness of National Board Certified (NBC) teachers in terms of classroom environment, attitudes abd achievement among secondary science students. *Learning Environments Research, 16*(1), 1-21.

Henderson, D., Fisher, D. L., & Fraser, B. J. (2000). Interpersonal behaviour, laboratory learning environments, and student outcomes in senior Biology classes. *Journal of Research in Science Teaching, 37*, 26-43.

Hilton, T. L., Hsia, J., Solorzano, D. G., & Benton, N. L. (1989). *Persistence in science of high-ability minority students*. Princeton, NJ: Educational Testing Service.

Hofstein, A., & Walberg, H. J. (1995). Instructional strategies. In B. J. Fraser & H. J. Walberg (Eds.), *Improving science education* (pp. 1-20). Chicago, IL: National Society for the Study of Education.

Hollingworth, L. S. (Ed.). (1940). Intelligence as an element of personality. In G. M. Whipple (Ed.), *Intelligence: Its nature and nurture: Part I. Comparative and critical exposition* (39th Yearbook of National Society for the Study of Education). Bloomington, IL: Public School Publishing.

Houston, L. S., Fraser, B. J., & Ledbetter, C. E. (2008). An evaluation of elementary school science kits in terms of classroom environment and student attitudes. *Journal of Elementary Science Education, 20*(4), 29-47.

Huang, S. Y. L., & Fraser, B. J. (2009). Science teachers' perceptions of the school environment: Gender differences. *Journal of Research in Science Teaching, 46*, 404-420.

Hunt, D. E. (1975). Person-environment interaction: A challenge found wanting before it was tried. *Review of Educational Research, 45*, 209-230.

Idiris, S., & Fraser, B. J. (1997). Psychosocial environment of agricultural science classrooms in Nigeria. *International Journal of Science Education, 19*, 79-91.

Jegede, O. J., Fraser, B. J., & Fisher, D. L. (1995). The development and validation of a distance and open learning environment scale. *Educational Technology Research and Development, 43*, 90-93.

Jegede, O. J., Fraser, B. J., & Okebukola, P. A. (1994). Altering socio-cultural beliefs hindering the learning of science. *Instructional Science, 22*, 137-152.

Jinks, J. L., & Morgan, V. (1999). Children's perceived academic self-efficacy: An inventory scale. *Clearing House, 72*, 224-230.

Johnson, B., & McClure, R. (2004). Validity and reliability of a shortened, revised version of the Constructivist Learning Environment Survey(CLES). *Learning Environments Research, 7*, 65-80.

Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement, 20*, 141-151.

Kaplan, A., & Maehr, M. L. (1999). Achievement goals and student well-being. *Contemporary Educational Psychology, 24*, 330-358.

Kaplan, A., & Maehr, M. L. (2007). The contribution and prospects of goal orientation theory. *Educational Psychology Review, 19*, 141-187.

Kerlinger, F. N. (1986). *Foundations of behavioral research* (3rd ed.). Fort Worth, TX: Holt, Rinehart, and Winston.

Khoo, H. S., & Fraser, B. J. (2008). Using classroom psychosocial environment in the evaluation of adult computer application courses in Singapore. *Technology, Pedagogy and Education, 17,* 67-81.

Kim, H. B., Fisher, D. L., & Fraser, B. J. (1999). Assessment and investigation of constructivist science learning environments in Korea. *Research in Science and Technological Education, 17*, 239-249.

Kim, H. B., Fisher, D. L., & Fraser, B. J. (2000). Classroom environment and teacher interpersonal behaviour in secondary school classes in Korea. *Evaluation and Research in Education, 14,* 3-22.

Kind, P. K., Jones, K., & Barmby, P. (2007). Developing attitudes towards science measures. *International Journal of Science Education, 29*, 871-893.

Klopfer, L. E. (1971). Evaluation of learning in science. In B. S. Bloom, J. T. Hastings, & G. F. Madaus (Eds.), *Handbook on summative and formative evaluation of student learning* (pp. 559-642). New York: McGraw-Hill.

Koh, N. K., & Fraser, B. J. (2014). Learning environment associated with use of mixed mode delivery model among secondary business studies students in SIngapore. *Learning Environments Research, 17*(2), 157-171.

Koren, J. A. (2013). *A comparative study of gifted and non-gifted middle-school students in terms of classroom environment and attitudes within a large urban school district* (Unpublished PhD thesis). Curtin University, Western Australia.

Koul, R., & Fisher, D. (2005). Background and students' perceptions of science classroom learning environment and teacher interpersonal behaviour in Jammu, India. *Learning Environments Research, 8*(2), 195-211.

Koul, R. B., Fisher, D. L., & Shaw, T. (2011). An application of the TROFLEI in secondary-school science classes in New Zealand. *Research in Science and Technological Education, 29*(2), 147-167.

Koul, R. B., & Fraser, B. J. (2005). Cultural background and students' perceptions of science classroom learning environment and teacher interpersonal behaviour in Jammu, India. *Learning Environments Research, 8*, 195-211.

Kupermintz, H. (2002). Affective and cognitive factors as aptitude resources in high school science achievement. *Educational Assessment, 8*, 123-137.

Laforgia, J. (1988). The affective domain related to science education and its evaluation. *Science Education, 72*, 407-421.

Logan, K. A., Crump, B. J., & Rennie, L. J. (2006). Measuring the computer classroom environment: Lessons learned from using a new instrument. *Learning Environments Research, 9*, 67-93.

Lee, S. S. U., Fraser, B. J., & Fisher, D. L. (2003). Teacher-student interactions in Korean high school science classrooms. *International Journal of Science and Mathematics Education, 1*, 67-85.

Lewin, K. (1936). *Principles of topological psychology*. New York: McGraw.

Lightburn, M. E., & Fraser, B. J. (2007). Classroom environment and student outcomes among students using anthropometry activities in high school science. *Research in Science and Technological Education, 25*, 153-166.

Lim, C. D. (2013). *Learning environments in English classrooms in Singapore: Determinants and effects* (Unpublished PhD thesis). Curtin University, Western Australia.

Lin, B., & Crawley, F. E., II. (1987). Classroom climate and science-related attitudes of junior high school students in Taiwan. *Journal of Research in Science Teaching, 24*(6), 579-591.

Liu, X., Macmillan, R. B., & Timmons, V. (1998). Integration of computers into the curriculum: How teachers may hinder students' use of computers. *McGill Journal of Education, 33*(1), 51-69.

Lockwood, A. (1992a). The de facto curriculum? *Focus in Change, 6*, 8-11.

Lockwood, A. (1992b). Whose knowledge do we teach? *Focus in Change, 6*, 3-7.

Long, C., & Fraser, B. J. (2015). Comparison of alternative sequencing of middle-school science curriculum: Classroom learning environment and student attitudes. *Curriculum and Teaching, 30*(1), 23-36.

Lott, K. H. (2003). Evaluation of a statewide science inservice and outreach program: Teacher and student outcomes. *Journal of Science Education and Technology, 12*(1), 65-80.

Lowe, J. P. (2004). *The effect of cooperative group work and assessment on the attitudes of students towards science in New Zealand* (Unpublished PhD thesis). Curtin University, Western Australia.

Loyd, B. D., & Gressard, C. (1984). Reliability and factorial validity of computer attitudes scales. *Educational and Psychological Measurement, 44,* 501-505.

Mackay, L. D. (1971). Changes in physics students in three states over a two year period. In R. P. Tisher (Ed.), *Research* (pp. 109-118). Melbourne, Australia: Australian Science Education Research Association.

MacLeod, C., & Fraser, B. J. (2010). Development, validation and application of a modified Arabic translation of the What is Happening In this Class? (WIHIC) questionnaire. *Learning Environments Research, 13,* 105-125.

Majeed, A., Fraser, B. J., & Aldridge, J. M. (2002). Learning environment and its association with student satisfaction among mathematics students in Brunei Darussalam. *Learning Environments Research*, *5*, 203-226.

Maor, D., & Fraser, B. J. (1996). Use of classroom environment perceptions in evaluating inquiry-based computer assisted learning. *International Journal of Science Education, 18,* 401-421.

Marjoribanks, K. (1991). Families, school, and students' educational outcomes. In B. J. Fraser & H. J. Walberg (Eds.), *Educational environments: Evaluation, antecedents and consequences* (pp. 75-91). London: Pergamon.

Martin-Dunlop, C., & Fraser, B. J. (2008). Learning environment and attitudes associated with an innovative course designed for prospective elementary teachers. *International Journal of Science and Mathematics Education, 6*, 163-190.

Martin, M.O., Mullis, I.V.S., Gonzalez, E.J., Gregory, K.D., Smith, T.A., Chrostowski, S.J., Garden, R.A., & O'Connor, K.M. (2000). *TIMSS 1999 International Science Report: Findings from IEA's repeat of the Third International Mathematics and Science Study* (TIMSS) *at the eighth grade* (Executive summary). Chestnut Hill, MA: Center for the Study of Testing, Evaluation, and Educational Policy, Boston College.

McRobbie, C. J., & Fraser, B. J. (1993). Associations between student outcomes and psychosocial science environment. *Journal of Educational Research, 87*, 78-85.

Midgley, C. (2002). *Goals, goal structures, and patterns of adaptive learning.* Mahwah. NJ: Lawrence Erlbaum.

Midgley, C., Eccles, J. S., & Feldlaufer, H. (1991). Classroom environment and the transition to junior high school. In B. J. Fraser & H. J. Walberg (Eds.), *Educational environments: Evaluation, antecedents and consequences* (pp. 113-139). London: Pergamon.

Ministry of Education, Singapore. (2016a). *Education System*. Retrieved August 8, 2016, from https://www.moe.gov.sg/education/education-system

Ministry of Education, Singapore. (2016b). *Gifted Education Programme*. Retrieved August 5, 2016, from https://www.moe.gov.sg/education/programmes/gifted-education-programme/rationale-and-goals

Ministry of Education, Singapore. (2016c). *Sciences*. Retrieved August 5, 2016, from https://www.moe.gov.sg/education/syllabuses/sciences/

Mink, D. V., & Fraser, B. J. (2005). Evaluation of a K─5 mathematics programme which integrates children's literature: Classroom environment and attitudes. *International Journal of Science and Mathematics Education, 3*, 58-85.

Misiti, F. L., Shrigley, R. L., & Hanson, L. (1991). Science attitude scale for middle school students. *Science Education, 75*, 525-540.

Mitra, A., & Steffensmeier, T. (2000). Changes in student attitudes and computer use in a computer-enriched environment. *Journal of Research on Computing in Education, 32*, 417-433.

Moore, R. W., & Foy, R. L. (1997). The Scientific Attitude Inventory: A revision (SAI II). *Journal of Research in Science Teaching, 34*, 327-336.

Moore, R. W., & Sutman, F. X. (1970). The development, field test and validation of an inventory of scientific attitude. *Journal of Research in Science Teaching, 7,* 85-94.

Moos, R. H. (1974). *The social climate scales: An overview*. Palo Alto, CA: Consulting Psychologist Press.

Moos, R. H. (1979). *Evaluating educational environments: Procedures, measures, findings and policy implications.* San Francisco, CA: Jossey-Bass.

Moos, R. H. (1981). *Manual for Work Environment Scale*. Palo Alto, CA: Consulting Psychologists Press.

Moos, R. H. (1991). Connections between school, work, and family settings. In B. J. Fraser & H. J. Walberg (Eds.), *Educational environments: Evaluation, antecedents and consequences* (pp. 29-53). London: Pergamon.

Moos, R. H., & Trickett, E. J. (1974). *Classroom Environment Scale manual*. Palo Alto, CA: Consulting Psychologists Press.

Mueller, D. J. (1986). *Measuring social attitudes. A handbook for researchers and practitioners.* New York: Teacher College Press.

Munby, H. (1980). An evaluation of instruments which measure attitudes to science. In C. P. McFadden (Ed.), *World trends in science education* (pp. 266-275). Halifax, Nova Scotia: Atlantic Institute of Education.

Munby, H. (1983). Thirty studies involving the "Scientific Attitude Inventory": What confidence can we have in this instrument? *Journal of Research in Science Teaching, 20*, 141-162.

Murray, H. A. (1938). *Explorations in personality*. New York: Oxford University Press.

National Association for Gifted Children. (2008). *A brief history of gifted and talented education*. Retrieved June 6, 2015, from http://www.nagc.org/resources-publications/resources/gifted-education-us/brief-history-gifted-and-talented-education

National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform*. Washington, DC: U.S. Government Printing Office.

National Library Board, Singapore. (2015). *Gifted Education Programme is introduced*. Retrieved June 8, 2015, from http://eresources.nlb.gov.sg/history/events/74f49f3c-3536-4ef0-8d33-8e985275fb85

National Library Board, Singapore. (2016). New Education System is introduced. Retrieved August 5, 2016 from http://eresources.nlb.gov.sg/history/events/832f0610-d78c-4560-a2d5-b72c2858ce1a

National Science Board Commission on Precollege Education in Mathematics, Science, and Technology. (1983). *Educating Americans for the 21st century*. Washington, DC: National Science Foundation.

Newhouse, C. P. (2001). Development and use of an instrument for computer-supported learning environments. *Learning Environments Research, 4*, 115-138.

Nix, R. K., & Fraser, B. J. (2011). Using computer-assisted teaching to promote constructivist practices in teacher education. In B. A. Morris & G. M. Ferguson (Eds.), *Computer-assisted teaching* (pp. 93-115). New York: Nova Science Publishers.

Nix, R. K., Fraser, B. J., & Ledbetter, C. E. (2005). Evaluating an integrated science learning environment using the Constructivist Learning Environment Survey. *Learning Environments Research*, *8*, 109-133.

Ogbuehi, P. L., & Fraser, B. J. (2007). Learning environment, attitudes and conceptual development associated with innovative strategies in middle-school mathematics. *Learning Environments Research, 10*, 101-114.

Ormerod, M. B., & Duckworth, D. (1975). *Pupils' attitudes to science*. Slough, England: National Foundation for Educational Research.

Osborne, J., & Simon, S. (1996). Primary science: Past and future directions. *Studies in Science Education, 27*(1), 99-147.

Oser, R., & Fraser, B. J. (2015). Effectiveness of virtual laboratories in terms of learning environment, attitudes and achievement among high-school genetics students. *Curriculum and Teaching, 30*(2), 65-80.

Pajares, F. (1996). Self-efficacy during childhood and adolescence: Implications for teachers and parents. In F. Pajares & T. Urdan (Eds.), *Adolescence and education: Self-efficacy beliefs of adolescents* (pp. 339-367). Greenwich, CT: Information Age Publishing.

Peer, J., & Fraser, B. J. (2015). Sex, grade-level and stream differences in learning environment and attitudes to science in Singapore primary schools. *Learning Environments Research, 18*(1), 143-161.

Peiro, M. M., & Fraser, B. J. (2009). Assessment and investigation of science learning environments in the early childhood grades. In M. Ortiz & C. Rubio (Eds.), *Educational evaluation: 21st century issues and challenges* (pp. 349-365). New York: Nova Science Publishers.

Perels, F., Gurtler, T., & Schmitz, B. (2005). Training of self-regulatory and problem-solving competence. *Learning and Instruction, 15*, 123-139.

Perrodin, A. F. (1966). Children's attitudes towards elementary school science. *Science Education, 50*, 214-218.

Pickett, L. H., & Fraser, B. J. (2009). Evaluation of a mentoring programme for beginning teachers in terms of the learning environment and student outcomes in participants' school classrooms. In A. Selkirk & M. Tichenor (Eds.), *Teacher education: Policy, practice and research* (pp. 1-52). New York: Nova Science Publishers.

Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. In P. R. Pintrich & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 451-502). San Diego, CA: Academic.

Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology, 95*, 667-686.

Pintrich, P. R., & De Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology, 82*, 33-40.

Pintrich, P. R., & Schunk, D. H. (1995). *Motivation in education: Theory, research, and applications*. Englewood Cliffs, NJ: Prentice Hall.

Plucker, J., & Esping, A. (2014). *Intelligence 101*. New York: Springer Publishing Company.

Quek, C. G. (1997). *An overview of the Singapore Gifted Education Programme (GEP)*. Paper presented at the 1st International Conference on Special Education, Brunei Darussalam.

Quek, C. L., Wong, A. F. L., & Fraser, B. J. (2005). Student perceptions of chemistry laboratory learning environments, student-teacher interactions and attitudes in secondary school gifted education classes in Singapore. *Research in Science Education, 35*, 299-321.

Reid, N. (2006). Thoughts on attitude measurement. *Research in Science and Technological Education, 24*, 3-27.

Rentoul, A. J., & Fraser, B. J. (1979). Conceptualization of enquiry-based or open classroom learning environments. *Journal of Curriculum Studies, 11*, 233-245.

Rentoul, A. J., & Fraser, B. J. (1983). Development of a school-level environment questionnaire. *Journal of Educational Administration, 21*, 21-39.

Robinson, E., & Fraser, B. J. (2013). Kindergarten students' and parents' perceptions of science classroom environments: Achievement and attitudes. *Learning Environments Research, 16*(2), 151-167.

Rogers, J. (2013). *Laboratory classroom environment, sex and frequency of practical work as determinants of middle-school science students' attitudes and* aspirations (Unpublished PhD thesis). Curtin University, Western Australia.

Sattler, J. M. (1992). *Assessment of children: Revised and updated* (3rd ed.). San Diego,CA: Jerome M. Sattler, Publisher, Inc.

Schibeci, R. A. (1984). Attitudes to science: An update. *Studies in Science Education, 11*, 26-59.

Schibeci, R. A., & McGaw, B. (1981). Empirical validation of the conceptual structure of a test of science related attitudes. *Educational & Psychological Measurement, 41*, 1195-1201.

Schriesheim, C. A., Eisenbach, R. J., & Hill, K. D. (1991). The effect of negation and polar opposite item reversals on questionnaire reliability and validity: An experimental investigation. *Educational and Psychological Measurement, 51*(1), 67-78.

Schriesheim, C. A., & Hill, K. D. (1981). Controlling acquiescence response bias by item reversals: The effect on questionnaire validity. *Educational and Psychological Measurement, 41*(4), 1101-1114.

Schunk, D. H. (1989). Self-efficacy and achievement behaviours. *Educational Psychology Review, 1*, 173-208.

Schunk, D. H. (2004). *Learning theories: An educational perspective*. Upper Saddle River, NJ: Pearson Prentice Hall.

Schunk, D. H., & Zimmerman, B. J. (2007). Influencing children's self-efficacy and self-regulation of reading and writing through modeling. *Reading & Writing Quarterly, 23*, 7-25.

Scott, R. H., & Fisher, D. L. (2004). Development, validation and application of a Malay translation of an elementary version of the Questionnaire on Teacher Interaction (QTI). *Research in Science Education, 34,* 173-194.

Shrigley, R. L. (1983). The attitude concept and science teaching. *Science Education, 67*, 425-442.

Silverman, L. K. (2013). *Giftedness 101*. New York: Springer.

Sinclair, B. B., & Fraser, B. J. (2002). Changing classroom environments in urban middle schools. *Learning Environments Research, 5,* 301-328.

Sink, C. A., & Spencer, L. R. (2005). My Class Inventory-Short Form as an accountability tool for elementary school counsellors to measure classroom climate. *Professional School Counseling, 9*, 37-48.

Stern, G. G. (1970). *People in context: Measuring person-environment congruence in education and industry.* New York: Wiley.

Stern, G. G., Stein, M. I., & Bloom, B. S. (1956). *Methods in personality assessment*. Glencoe, IL: Free Press.

Stolarchuk, E., & Fisher, D. (2001). First years of laptops in science classrooms result in more learning about computers than science. *Issues in Educational Research, 11*(1), 25-39.

Tapia, M., & Marsh, G. (2004). An instrument to measure mathematics attitudes. *Academic Exchange Quarterly, 8*(2), 1-8.

Taylor, B., & Fraser, B. J. (2013). Relationships between learning environment and mathematics anxiety. *Learning Environments Research, 16*(2), 297-313.

Taylor, P. C., Fraser, B. J., & Fisher, D. L. (1997). Monitoring constructivist classroom learning environments. *International Journal of Educational Research, 27*, 293-302.

Teh, G. L., & Fraser, B. J. (1994). An evaluation of computer-assisted learning in terms of achievement, attitudes and classroom environment. *Evaluation & Research in Education, 8*(3), 147-159.

Teh, G., & Fraser, B. J. (1995). Associations between student outcomes and geography classroom environment. *International Research in Geographical and Environmental Education, 4*(1), 3-18.

Telli, S., den Brok, P., & Cakiroglu, J. (2010). The importance of teacher-student interpersonal relationships for Turkish students' attitudes towards science. *Research in Science and Technological Education, 28*, 261-276.

Teo, T. (2006). Attitudes toward computers: A study of post-secondary students in Singapore. *Interactive Learning Environments, 14*(1), 17-24.

Terman, L. M. (1925). *Mental and physical traits of a thousand gifted children: Genetic studies of genius* (Vol. 1). Stanford, CA: Stanford University Press.

Theobald, M. A. (2006). *Increasing student motivation: Strategies for middle and high school teachers.* Thousand Oaks, CA: Corwin.

Thorp, H., Burden, R. L., & Fraser, B. J. (1994). Assessing and improving classroom environment. *School Science Review, 75*, 107-113.

Thurstone, L. L. (1928). Attitudes can be measured. *American Journal of Sociology, 33*, 529-544.

Tobin, K., & Fraser, B. J. (1998). Qualitative and quantitative landscapes of classroom learning environments. In B.J. Fraser and K. G. Tobin (Eds.), *International handbook of science education* (pp. 623-640). Dordrecht, The Netherlands: Kluwer.

Tobin, K., Kahle, J. B., & Fraser, B. J. (Eds.). (1990). *Windows into science classes: Problems associated with higher-level cognitive learning*. London: Falmer Press.

Torrance, E. P., & Mourad, S. (1978). Some creativity and style of learning and thinking correlates of Guglielmino's Self-directed Readiness Scale. *Psychological Reports, 43*, 1167-1171.

Treffinger, D. J. (1975). Teaching for self-directed learning: A priority for the gifted and talented. *Gifted Child Quarterly, 29*, 46-59.

Trickett, E. J., & Moos, R. H. (1973). Social environment of junior high and high school classrooms. *Journal of Educational Psychology, 65*, 93-102.

Tuan, H., Chin, C., & Shieh, S. (2005). The development of a questionnaire to measure students' motivation towards science learning. *International Journal of Science Education, 27*, 639-654.

Van Tassel-Baska, J. (1986). Acceleration. In J. Maker (Ed.), *Critical issues in gifted education* (pp. 179-186). Rockville, MD: Aspen.

Van Tassel-Baska, J. (1987). The ineffectiveness of the pull-out programme model in gifted education: A minority perspective. *Journal of Education of the Gifted, 10*(4), 255-264.

Van Tassel-Baska, J. (2003). What matters in curriculum for gifted learners: Reflection on theory, research and practice. In N. Colangelo & G.A. Davis (Eds.), *Handbook of gifted education* (3rd ed., pp. 174-183). Boston: Allyn & Bacon.

Van Tassel-Baska, J., Bass, G., Reis, R., Poland, D., & Avery L.D. (1998). A national study of science curriculum effectiveness with high ability students. *Gifted Child Quarterly, 42 (4)*, 200-211.

Van Tassel-Baska, J., & Stambaugh, T. (2006). *Comprehensive curriculum for gifted learners*. Boston: Pearson Education, Inc.

Velayutham, S., & Aldridge, J. M. (2013). Influence of psychosocial classroom environment on students' motivation and self-regulation in science learning: A structural equation modeling approach. *Research in Science Education, 43*(2), 507-527.

Velayutham, S., Aldridge, J. M., & Fraser, B. J. (2011). Development and validation of an instrument to measure students' motivation and self-regulation in science learning. *International Journal of Science Education, 33*(15), 2159-2179.

Velayutham, S., Aldridge, J. M., & Fraser, B. J. (2012). Gender differences in student motivation and self-regulation in science learning: A multi-group structural equation structural modelling analysis. *International Journal of Science and Mathematics Education, 10*(6), 1347-1368.

Wahyudi, & Treagust, D. F. (2004). The status of science classroom learning environments in Indonesian lower secondary schools. *Learning Environments Research, 7,* 43-63.

Walberg, H. J. (1986). Synthesis of research on teaching. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 214-229). Washington, DC: American Educational Research Association.

Walberg, H. J., & Anderson, G. J. (1968). Classroom climate and individual learning. *Journal of Educational Psychology, 59,* 414-419.

Walberg, H. J., & Anderson, G. J. (1972). Properties of the achieving urban classes. *Journal of Educational Psychology, 63,* 381-385.

Walberg, H. J., Fraser, B. J., & Welch, W. W. (1986). A test of a model of educational productivity among senior high school students. *Journal of Educational Research, 79,* 133-139.

Walker, S. L. (2006). Development and validation of the Test of Geography-Related Attitudes (ToGRA). *Journal of Geography, 105*, 175-181.

Walker, S. L., & Fraser, B. J. (2005). Development and validation of an instrument for assessing distance education learning environments in higher education: The Distance Education Learning Environments Survey (DELES). *Learning Environments Research, 8*, 267-287.

Wechsler, D. (1939). *The measurement of adult intelligence*. Baltimore, MD: William & Wilkins.

Wechsler, D. (1949). *Wechsler intelligence scale for children*. San Antonio, TX: The Psychological Corporation.

Welch, A. G., Cakir, M., Peterson, C. M., & Ray, C. M. (2012). A cross-cultural validation of the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) in Turkey and the USA. *Research in Science and Technological Education, 30*(1), 49-63.

Welch, A. G., Cakir, M., Peterson, C. M., & Ray, C. M. (2014). The relationship between gender and classroom environment in Turkish science classrooms. *Educational Research and Reviews, 9*(20), 893-903.

Withall, J. (1949). The development of a technique for the measurement of socio-emotional climate in classrooms. *Journal of Experimental Education, 17,* 347-361.

Wolf, S. J., & Fraser, B. J. (2008). Learning environment, attitudes and achievement among middle-school science students using inquiry-based laboratory activities. *Research in Science Education, 38,* 321-341.

Wolters, C. A., & Rosenthal, H. (2000). The relation between students' motivational beliefs and their use of motivational regulation strategies. *International Journal of Educational Research, 33*, 801-820.

Wong, A. F. L., & Fraser, B. J. (1995). Cross-validation in Singapore of the science laboratory environment inventory. *Psychological Reports, 76*(3), 907-911.

Wong, A. L. F., & Fraser, B. J. (1996). Environment-attitudes associations in the chemistry laboratory classroom. *Research in Science and Technological Education, 14,* 91-102.

Wong, A. L. F., Young, D. J., & Fraser, B. J. (1997). A multilevel analysis of learning environments and student attitudes. *Educational Psychology, 17*, 449-468.

Woods, J., & Fraser, B. J. (1996, April). *Enhancing reflection by monitoring students' perceptions of teaching style and preferred learning style*. Paper presented at the annual meeting of the American Educational Research Association, New York.

Wubbels, T., & Brekelmans, M. Y. (1998). The teacher factor in the social climate of the classroom. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 565-580). Dordrecht, The Netherlands: Kluwer.

Wubbels, T., & Brekelmans, M. (2012). Teacher-students relationship in a classroom. In B. J. Fraser, K. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 1241-1255). Dordrecht, The Netherlands: Springer.

Wubbels, T., Brekelmans, M. Y., & Hooymayers, H. (1991). Interpersonal teacher behaviour in the classroom. In B. J. Fraser, & H. J. Walberg (Eds.), *Educational environments: Evaluation, antecedents and consequences* (pp. 141-160). London, UK: Pergamon Press.

Wubbels, T., & Levy, J. (Eds.). (1993). *Do you know what you look like? Interpersonal relationships in education.* London: Falmer Press.

Yarrow, A., & Millwater, J. (1995). SMILE: Student Modification In Learning Environments─Establishing congruence between actual and preferred classroom learning environment. *Journal of Classroom Interaction, 30*(1), 11-15.

Yarrow, A., Millwater, J., & Fraser, B. J. (1997). Improving university and primary school classroom environments through preservice teachers' action research. *International Journal of Practical Experiences in Professional Education, 1*(1), 68-93.

Yurkevich, V. S., & Davidovich, B. M. (2009). Russian strategies for talent development: Stimulating comfort and discomfort. In T. Balchin, Hymer, B. & Matthews, D. J. (Eds.), *The Routledge international companion to gifted education* (pp. 101-105). New York: Routledge.

Zandvliet, D. B., & Fraser, B. J. (2004). Learning environments in information and communications technology classrooms. *Technology, Pedagogy and Education*, *13*, 97-123.

Zandvliet, D. B., & Fraser, B. J. (2005). Physical and psychosocial environments associated with networked classrooms. *Learning Environments Research, 8*, 1-17.

Zenderland, L. (1998). *Measuring minds: Henry Herbert Goddard and the origins of American intelligence testing*. Cambridge: Cambridge University Press.

Zimmerman, B. J. (2000). Self-efficacy: An essential motive to learn. *Contemporary Educational Psychology, 25*, 82-91.

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory Into Practice, 41*, 64-70.

Zimmerman, B. J., Bandura, A., & Martinez-Pons, M. (1992). Self-motivation for academic attainment: The role of self-efficacy beliefs and personal goal setting. *American Educational Research Journal, 29*, 663-676.

APPENDICES

Appendix A

Learning Environment and Student Attitude Questionnaire

In this questionnaire, Items 1–40 are based on the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI, Dorman et al., 2006), Items 41–48 are based on the Constructivist-Orientated Learning Environment Survey (COLES, Aldridge et al., 2012), Items 49–56 are based on the Attitude and Efficacy Questionnaire (AEQ, Aldridge & Fraser, 2008), Items 57–80 are based on the Students' Adaptive Learning Engagement in Science (SALES, Velayutham et al., 2011). These questionnaire items were used in my study and are included in this thesis with the authors' permission.

Directions for Students

Part I of the questionnaire contains statements (1 to 48) about practices that could take place in this class. You will be asked how often each practice takes place.

Part II of the questionnaire contains statements (49 to 80) about you as a student in this class. Choose the option that best describes what you think about the statements.

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.

Be sure to give an answer for all questions. If you change your mind about an answer, you would change before you submit.

Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.

Practice Example

Suppose you were given the statement "I choose my partners for group discussion." You would need to decide whether you choose your partners 'Almost always', 'Often', 'Sometimes', 'Seldom' or 'Almost never'. If you selected 'Often' then you would click the number 4 on your questionnaire.

Part I

In this class…		Almost Never	Seldom	Some-times	Often	Almost Always
1.	I carry out investigations to test my ideas.	1	2	3	4	5
2.	I am asked to think about the evidence for statements.	1	2	3	4	5
3.	I carry out investigations to answer questions coming from discussions.	1	2	3	4	5
4.	I explain the meaning of statements, diagrams and graphs.	1	2	3	4	5
5.	I carry out investigations to answer questions which puzzle me.	1	2	3	4	5
6.	I carry out investigations to answer the teacher's questions.	1	2	3	4	5
7.	I find out answers to questions by doing investigations.	1	2	3	4	5
8.	I solve problems by using information obtained from my own investigations.	1	2	3	4	5
9.	Getting a certain amount of work done is important to me.	1	2	3	4	5
10.	I do as much as I set out to do.	1	2	3	4	5
11.	I know the goals for this class.	1	2	3	4	5
12.	I am ready to start this class on time.	1	2	3	4	5
13.	I know what I am trying to accomplish in this class.	1	2	3	4	5
14.	I pay attention during this class.	1	2	3	4	5
15.	I try to understand the work in this class.	1	2	3	4	5
16.	I know how much work I have to do.	1	2	3	4	5
17.	I cooperate with other students when doing assignment work.	1	2	3	4	5
18.	I share my books and resources with other students when doing assignments.	1	2	3	4	5
19.	When I work in groups in this class, there is teamwork.	1	2	3	4	5
20.	I work with other students on projects in this class.	1	2	3	4	5

In this class…		Almost Never	Seldom	Some-times	Often	Almost Always
21.	I learn from other students in this class.	1	2	3	4	5
22.	I work with other students in this class.	1	2	3	4	5
23.	I cooperate with other students on class activities.	1	2	3	4	5
24.	Students work with me to achieve class goals.	1	2	3	4	5
25.	I work at my own pace.	1	2	3	4	5
26.	Students who work faster than me move on to the next topic.	1	2	3	4	5
27.	I am given a choice of topics.	1	2	3	4	5
28.	I am set tasks that are different from other students' task.	1	2	3	4	5
29.	I am given work that suits my ability.	1	2	3	4	5
30.	I use different materials from those used by other students.	1	2	3	4	5
31.	For some assessments, I choose a type of presentation that is different from that chosen by other students.	1	2	3	4	5
32.	I do work that is different from other students' work.	1	2	3	4	5
33.	I use the computer to type my assignments.	1	2	3	4	5
34.	I use the computer to email assignments to my teacher.	1	2	3	4	5
35.	I use the computer to ask the teacher questions.	1	2	3	4	5
36.	I use the computer to find out information about the course.	1	2	3	4	5
37.	I use the computer to read lesson notes prepared by the teacher.	1	2	3	4	5
38.	I use the computer to find out information about how my work will be assessed.	1	2	3	4	5
39.	I use the computer to take part in online discussions with other students.	1	2	3	4	5
40.	I use the computer to obtain information from the Internet.	1	2	3	4	5

In this class…	Almost Never	Seldom	Some-times	Often	Almost Always
41. I use feedback from assessment tasks/assignments to improve my learning.	1	2	3	4	5
42. Assessment tasks/assignments help me to understand the topics.	1	2	3	4	5
43. There is link between classroom activities and my assessment tasks/assignments.	1	2	3	4	5
44. Assessment tasks/assignments help my understanding.	1	2	3	4	5
45. Assessment tasks/assignments are an important part of my learning.	1	2	3	4	5
46. Assessment tasks/assignments help me to understand weakness in my understanding.	1	2	3	4	5
47. Assessment tasks/assignments help me to monitor my own learning.	1	2	3	4	5
48. I find the assessment tasks/assignments meaningful.	1	2	3	4	5

Part II

In this class…	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
49. I am good at computers.	1	2	3	4	5
50. I like working with computers.	1	2	3	4	5
51. Working with computers inspires me.	1	2	3	4	5
52. I am comfortable trying new software on the computer.	1	2	3	4	5
53. Working with computers is motivating.	1	2	3	4	5
54. Working on a computer makes my work more enjoyable.	1	2	3	4	5
55. I do as much work as I can using a computer.	1	2	3	4	5
56. I feel comfortable using a computer.	1	2	3	4	5
57. The lessons I learn can be used in my daily life.	1	2	3	4	5
58. The lessons I learn stimulates my thinking.	1	2	3	4	5
59. The lessons I learn satisfies my curiosity.	1	2	3	4	5
60. The lessons I learn is helpful to me.	1	2	3	4	5
61. The lessons I learn is relevant to me.	1	2	3	4	5
62. The lessons I learn is of practical value.	1	2	3	4	5
63. The lessons I learn is interesting.	1	2	3	4	5
64. The lessons I learn is useful for me to know.	1	2	3	4	5

	In this class…	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
65.	I can master the skills that are taught.	1	2	3	4	5
66.	I can figure out how to do difficult work.	1	2	3	4	5
67.	Even if the class work is hard, I can learn it.	1	2	3	4	5
68.	I can do even the hardest work if I try.	1	2	3	4	5
69.	I will receive a good grade.	1	2	3	4	5
70.	I can learn the material.	1	2	3	4	5
71.	I can understand the concepts taught.	1	2	3	4	5
72.	I am good at this subject.	1	2	3	4	5
73.	Even when tasks are uninteresting, I keep working.	1	2	3	4	5
74.	I work hard even if I do not like what I am doing.	1	2	3	4	5
75.	I get myself to learn even when there are other things to do (e.g. reading a novel, Facebook).	1	2	3	4	5
76.	I concentrate so that I won't miss important points.	1	2	3	4	5
77.	I finish my work and assignments on time.	1	2	3	4	5
78.	I don't give up even when the work is difficult.	1	2	3	4	5
79.	I concentrate to remember information presented in class.	1	2	3	4	5
80.	I never quit until I finish what I am supposed to do.	1	2	3	4	5

Appendix B

Parent Information Sheet

G Sundari, M.Ed.
Research Investigator

Curtin University
Science and Mathematics Education Centre

Parent/Guardian Information Sheet

My name is G Sundari and I am currently completing a piece of research for my degree of Doctor of Philosophy at Curtin University in Perth, Western Australia.

Purpose of Research
I am investigating both the learning experiences and attitudes of technology-based and regular science classrooms of female gifted students in Singapore.

Your Child's Role
I am interested in comparing data obtained from technology-based and regular science classrooms of female gifted students with the purpose of assessing students' classroom environment and attitudes. Your child will be asked to complete two surveys that will be administered during one of her normal science class periods. This entire process will take approximately 35 minutes.

Consent to Participate
Your child's involvement in this research is entirely voluntary. She has the right to withdraw at any stage without it affecting her rights or my responsibilities. Once you and your child have signed the consent forms, I will assume that you have agreed to allow your child to participate in this study and that I have your permission to use the data in this research.

Confidentiality
The information your child provides will be kept separate from her personal details, and only my supervisor and I will have access to the completed questionnaires. These questionnaires will be kept in a locked cabinet for five (5) years at which point they will be destroyed.

Further Information
This research has been reviewed and given approval by the Curtin University Human Research Ethics Committee (Approval Number SMEC 33-13). If you would like further information about this study, please feel free to contact me at sundariprama@gmail.com or (+65) 91723541. Alternatively, you may contact my supervisor, Professor Barry J. Fraser, at B.Fraser@curtin.edu.au.

Should you wish to make a complaint on ethical grounds, please contact the Human Research Ethics Committee Secretary at hrec@curtin.edu.au or via post at Office of Research Development, Curtin University, GPO Box U1987, Perth, Western Australia 6845.

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

Appendix C

Parent/Guardian Consent Form

G Sundari, M.Ed.
Research Investigator

Curtin University
Science and Mathematics Education Centre

Dear Parent/Guardian:

Permission is requested for ____ to participate in a teacher-based research study. The purpose of the research is to investigate both the learning experiences and attitudes of technology-based and regular science classrooms of female gifted students. Participants will be asked to be involved in the completion of two surveys. The entire process will take approximately 35 minutes.

The contact will be non-intrusive and will not disrupt classroom lessons. **The student samples will not be identifiable and confidentiality of all participants will be maintained.** Participation in this study will be beneficial in investigating the classroom environment and attitudes amongst female gifted students in a secondary school in Singapore.

Please indicate below whether you give permission for the above named student to participate in this valuable research study. Forms should be returned to the students' teacher. I will be the individual responsible for this research. Should you have any questions, feel free to contact me at (+65) 91723541 or via e-mail at sundariprama@gmail.com.

Sincerely,

G Sundari, M.Ed.

____**YES, permission is GRANTED to participate.**
____**No, permission is DENIED to participate.**

________________________________	________________________________
Parent/Guardian Name (Signature)	Parent/Guardian Name (Signature)
________________________________	________________________________
Parent/Guardian Name (Print)	Parent/Guardian Name (Print)
________________________________	________________________________
Date	Date

Appendix D

Student Participant Information Sheet

G Sundari, M.Ed.
Research Investigator

Curtin University
Science and Mathematics Education Centre

My name is G Sundari and I am currently completing a piece of research for my degree of Doctor of Philosophy at Curtin University in Perth, Western Australia.

Purpose of Research

I am investigating both the learning experiences and attitudes of technology-based and regular science classrooms of female gifted students in Singapore.

Your Role

I am interested in comparing data obtained from technology-based and regular science classrooms of female gifted students with the purpose of assessing students' classroom environment and attitudes. You will be asked to complete two surveys that will be administered during one of her normal science class periods. This entire process will take approximately 35 minutes.

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 or my responsibilities. Once 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 my supervisor and I will have access to the questionnaires you complete. These questionnaires will be kept in a locked cabinet for five (5) years at which point they will be destroyed.

Further Information

This research has been reviewed and given approval by the Curtin University Human Research Ethics Committee (Approval Number SMEC 33-13). If you would like further information about this study, please feel free to contact me at sundariprama@gmail.com or (+65) 91723541. Alternatively, you may contact my supervisor, Professor Barry J. Fraser, at B.Fraser@curtin.edu.au.

Should participants wish to make a complaint on ethical grounds, please contact the Human Research Ethics Committee Secretary at hrec@curtin.edu.au or via post at Office of Research Development, Curtin University, GPO Box U1987, Perth, Western Australia 6845.

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

Appendix E

Student Participant Consent Form

G Sundari, M.Ed.
Research Investigator

Curtin University
Science and Mathematics Education Centre

- I understand the purpose and procedures of the study.
- I have been provided with a *Student Participant Information Sheet*.
- I understand that the study itself may not benefit me.
- I understand that my involvement is voluntary and that I can withdraw from participating at any time without penalty or problems.
- I understand that no personal identifying information, such as my name and address, will be used in any published materials.
- I understand that all information related to this study, including completed questionnaires, will be securely stored for a period of five (5) after which it will 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 (Print)

____
Signature

____
Date

____
Student ID Number

Appendix F

Principal Permission Letter

G Sundari, M.Ed.
Research Investigator

Curtin University
Science and Mathematics Education Centre

My name is G Sundari and I am currently working on my doctoral degree with Curtin University in Perth, Western Australia. I wish to request permission for students in your school to participate in a teacher-based research study. The purpose of the research is to both the learning experiences and attitudes of technology-based and regular science classrooms of female gifted students in Singapore.

I would like to administer classroom environment and attitude surveys during the months of July and August 2014.

Student participants will be asked to be involved in the completion of two surveys. The entire process will take approximately 35 minutes. The contact will be non-intrusive and will not disrupt classroom lessons. The student samples will not be identifiable and confidentiality of all participants will be maintained.

Participation in this study will be beneficial in investigating the learning experiences and outcomes of technology-based and regular science classrooms of female gifted students in Singapore.

Included in this correspondence is a copy of my approval letter from Curtin University's Human Research Ethics Committee (Approval Number SMEC 33-13).

I will be the individual responsible for this research. Should you have any questions, feel free to contact me at (+65) 91723541 or via e-mail at sundariprama@gmail.com. Alternatively, you may contact my supervisor, Professor Barry J. Fraser, at B.Fraser@curtin.edu.au.

Best regards,

G Sundari, M.Ed.
Research Investigator, Curtin University
10 Reveley Court
Samson, WA 6163

Appendix G

Ethics Approval from Curtin University

Curtin University

Memorandum

To	G Sundari, SMEC
From	Pauline Howat, Administrator, Human Research Ethics Science and Mathematics Education Centre
Subject	Protocol Approval **SMEC-33-13**
Date	29 August 2013
Copy	Barry Fraser, 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 *"Gifted female students' attitudes and perceptions of their learning environment in technology-based and regular science classrooms in a Singapore 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 4 years **21st August 2013** to **20th August 2017**.

Your approval has the following conditions:

(i) Annual progress reports on the project must be submitted to the Ethics Office.

(ii) It is your responsibility, as the researcher, to meet the conditions outlined above and to retain the necessary records demonstrating that these have been completed.

The approval number for your project is **SMEC-33-13**. Please quote this number in any future correspondence. If at any time during the approval term changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately.

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 xxxx). 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.

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