Science and Mathematics Education Centre

The Learning Environment in Singapore Primary Science Classrooms: The Ideal and the Real

Goh Su Fen

This thesis is presented for the degree of
Doctor of Philosophy
of
Curtin University

January 2014

DECLARATION

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of my knowledge and belief, this thesis contains no material previously published by any person except where due acknowledgement has been made.

Signature:

Date: January 2014

ABSTRACT

In this study, I validated a modified learning environment and attitude questionnaire, the Science Learning Environment and Attitude Questionnaire (SLEAQ), specific to primary science classrooms in Singapore, investigated differences between students' perceptions of their actual and preferred classroom learning environments, examined sex differences in learning environment perceptions and attitudes to science, and investigated associations between students' attitudes and the nature of the classroom learning environment. The research was carried out in four similar government-run co-educational primary schools in Singapore with a sample of 485 students in 16 classes.

The SLEAQ is made up of two parts, with one section consisting of items which assess the science learning environment and the other section being made up of items which assess student attitudes. The section of the questionnaire assessing the science learning environment was modified from scales selected from the What Is Happening In this Class? (WIHIC) (Involvement, Investigation and Cooperation) and the Constructivist Learning Environment Survey (CLES) (Student Negotiation). An additional scale of Connection, developed for this study, was also included. Two scales (Attitude to Scientific Inquiry and Enjoyment of Science Lessons) from the Test of Science-Related Attitudes (TOSRA) were used to assess students' attitudes towards science. Data analysis supported the SLEAQ's factorial validity, internal consistency reliability, and its ability to differentiate between classrooms when used in Singaporean mainstream primary science classrooms.

Use of MANOVA revealed that actual–preferred differences were statistically significant different ($p<0.001$) between actual and preferred scores for each learning environment scale in the SLEAQ. The effect size for actual–preferred differences for different learning environment scales ranged from 0.81 to 1.07 standard deviations, placing them in the large magnitude range (Cohen, 1998).

MANOVA also revealed that, relative to females, male students perceived significantly ($p<0.01$) more actual Involvement and significantly less actual Cooperation and preferred significantly less Cooperation. The effect sizes for sex

differences for these scales were -0.33 standard deviations (actual Involvement), 0.37 (actual Cooperation) and 0.36 (preferred Cooperation), suggesting a relatively small difference between the sexes (using Cohen's criteria). For sex differences, male and female students had similar Attitude to Inquiry scores, but male students reported significantly greater Enjoyment of their Science Lessons compared to their female counterparts.

All learning environment scales were significantly and positively correlated with both Attitude to Inquiry and Enjoyment of Science Lessons. The multiple correlation analysis for the set of learning environment scales was statistically significant for both Attitude to Inquiry and Enjoyment of Science Lessons. An examination of the standardised regression coefficient for each scale revealed that Connection was a significant independent predictor to Attitude to Inquiry, whereas Involvement, Cooperation and Connection were significant independent predictors of Enjoyment of Science Lessons.

On the whole, my results suggest that the SLEAQ is a valid and reliable instrument that can be used to measure and investigate primary school children's perceptions of learning environment and attitudes in mainstream science classes in Singapore.

ACKNOWLEDGEMENTS

I would like to acknowledge a number of people who made this thesis completion a possibility. Most of all, I thank Jesus who has walked every step with me on this journey. Never did I ever imagine that I would be able to accomplish this. The journey is made even sweeter as He plants precious people along the way to constantly love and encourage me.

The first person that I would like to thank is the late Professor Colin Marsh for seeding the idea of pursuing a higher degree. His passion for life will always be a source of inspiration to me.

Thanks also to Professor Barry Fraser who deserves more credit than mere words can express. His guidance, understanding and support throughout have made this journey possible. I have been truly blessed to have him as my supervisor.

Thank you to Dr Rekha Koul for assisting me with the analysis and interpretation of the data. Her time and patience in helping me understand what those numbers and symbols meant in my study always will be something for which I will be grateful.

Thank you to my wonderful principals, Mrs Wong Bin Eng and Mrs Sharon Boey, for having faith in me and being my strong pillars of support at work. Their invaluable encouragement has kept me going.

A very sincere thank you also goes to all the enthusiastic students and teachers who assisted so willingly in this study with their contributions.

Thanks again to my family who, throughout the years, have supported me and have sown encouragement each step of the way – my mother, Suying, Eric, Benjamin, Rosaline and Aron for backing me and simply believing in me.

I would like to say a special thank you to my best friend, Donna, who embarked on this higher degree journey together with me. I could not have asked for a better best friend and I was glad for your support as we went through the many happy as well as the heart-stopping moments during this journey.

Last, but not less important, thank you to my group of 'circle of trust' friends from way back, Angela, Elaine, Jasmine, Jonathan and Su Yin, whose support includes being my 'alarm clock' and waking me up to work on my thesis. I am indeed privileged to have your friendship.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION AND OVERVIEW

1.1 Introduction

The emphasis on teaching science as inquiry is documented in the implementation of the 2008 primary science syllabus, which provides teachers in Singapore with a better understanding on what inquiry is and how it can be translated into the classroom (CPDD, 2007). To ensure that teachers are equipped to meet the great demands placed on them both in content knowledge and in the effective facilitation of inquiry, the Ministry of Education (MOE) has put in place systematic training for all primary science teachers in the teaching of science, particularly in inquiry teaching methods.

In Singapore, although there already have been studies contributing to a growing pool of learning environment research for over a decade (e.g. Chionh & Fraser, 2009; Chua, Wong & Chen, 2011; Goh & Fraser, 1998; Khoo & Fraser, 2008; Quek, Wong & Fraser, 2005; Teh & Fraser, 1994, 1995; Wong & Fraser, 1996), except for a study which was conducted among gifted primary science students (Peer & Fraser, in press), there have been no studies of mainstream primary schools to find out from young students their perceptions of their science classroom learning environments. As a researcher, I was interested in identifying how students respond to their science classrooms that are taught with an emphasis on the use of inquiry. I hope that this study will also provide teachers with better insights into their classrooms and help them to adjust their instructional delivery.

The foci of my study were to investigate:

- the reliability and validity of a science learning environment and attitude questionnaire for use by primary science students in Singapore;
- differences between students’ perceptions of their actual and preferred learning environments;
- sex difference in learning environment and attitudes to science;

- relationships between the learning environment and students' attitudes.

Data were gathered from 485 primary six students from 16 different mainstream science classes in 4 different co-educational schools in Singapore.

This chapter provides the background, a rationale and an overview of the study under the following headings:

- Context of the Study (Section 1.2)
  - Primary Science Education in Singapore (1.2.1)
  - Science Curriculum Framework (Section 1.2.2)
  - Teaching and Learning of Primary Science (1.2.3)
- Theoretical Framework (Section 1.3)
- Purposes of the Study (Section 1.4)
- Significance of the Study (Section 1.5)
- Overview of the Thesis (Section 1.6).

1.2 Context of the Study

My study took place in Singapore, a densely-populated nation state of about 647 square kilometres in size. It has a population size of about five million, which is mainly grouped into the four major ethnic communities of Chinese, Malay, Indian and Eurasians, roughly in the proportions of 75:13:9:3. There are four official languages: English, Chinese, Malay and Tamil, with English being the main language for government and business transactions, as well as for inter-racial communication. Singaporeans live in ethnically-mixed housing estates and neighbourhoods, and their children attend racially-integrated schools.

The national education system in Singapore provides equal opportunities for each student to learn and to achieve his or her potential. The role of education has always been pivotal in the growth and development of Singapore, particularly in the years following 1965 when it separated from Malaysia and became an independent republic. Now in the 21st century, when the knowledge-based economy is the driver in the global community, education has become even more critical in shaping the future of this nation.

In Singapore, the mission of the education service is to mould the future of the nation. The Ministry of Education (MOE) does so by designing for students a balanced and holistic education which strives to develop their potential to the fullest, and to develop them into good citizens with a sound awareness of their responsibility to family, society and nation.

The education scene in Singapore has evolved over the years, with it initially starting from its traditional British-based education system to one that endeavours to meet the needs of individuals and seeks to nurture talents. The government has also ensured that education is made affordable so that all Singapore children have the opportunity to be educated. Through years of effort, Singapore has achieved almost universal education at the primary and the secondary levels, with only a small percentage of the cohort of children not being enrolled in national schools today. To ensure that this small group of children are also equipped with the necessary skills and knowledge to be productive citizens in a knowledge-based economy, the government passed a law to make education compulsory in the year 2003. Compulsory education is implemented to ensure that all children in Singapore have the opportunity to be educated up to primary six as this is considered to be the minimum period of education (MOE, 2013). The two key objectives of compulsory education are to ensure that all children in Singapore are given:

- a common core of knowledge which provides a strong foundation for further education and training to prepare them for a knowledge-based economy;
- a common educational experience which helps to build national identity and cohesion.

With the government ensuring that the children of Singapore are provided with a school experience minimally from primary one to primary six, this would mean that the majority of Singaporean students spend a significant amount of their time in classrooms in their growing years. It therefore is important to ensure the quality of learning in these classrooms and also to study the learning environment and make changes accordingly so as to make teaching and learning more effective.

1.2.1 Primary Science Education in Singapore

In Singapore, primary science is formally introduced at primary three instead of primary one to allow students more time for the acquisition and mastery of English Language, Mother Tongue and Mathematics during their first two years of formal education.

Primary science education in Singapore aims to provide students with experiences which build on their interest in, and stimulate their curiosity about, their environment. Through these experiences, students will also be equipped with basic scientific terms and concepts to help them to understand themselves and the world around them and to develop skills, habits of mind and attitudes necessary for scientific inquiry. This education not only prepares students to use scientific knowledge and methods in making sound decisions and helps them to appreciate how science influences people and the environment (CPDD, 2007), but it also lays the foundation for various scientific studies at higher levels.

One of the sections in the 2008 primary science syllabus (CPDD, 2007) states that the approach to the learning of science in primary schools is based on themes to which students can relate in their everyday experiences and on commonly-observed phenomena in nature. The aim is to enable students to appreciate the links between different themes and topics and thus allow the integration of scientific ideas. The five themes are Diversity, Cycles, Systems, Energy and Interactions.

Table 1.1 shows the core body of concepts in both life and physical sciences encompassed within each of the themes which students would experience as they go through their education in primary school. This body of concepts has been chosen because it provides a broad-based understanding of the environment and it helps to build a foundation upon which students can rely for further study.

Table 1.1 Overview of the Singaporean Primary Science Syllabus

Themes	Topics in Lower Block (Primary 3 and 4)	Topics in Upper Block (Primary 5 and 6)
Diversity	Diversity of living and non-living things (General characteristics and classification) Diversity of materials	
Cycles	Cycles in plants and animals (Life cycles) Cycles in matter and water (Matter)	Cycles in plants and animals (Reproduction) Cycles in matter and water (Water)
Systems	Plant system (Plant parts and functions) Human system (Digestive system)	Plant system (Respiratory and circulatory systems) Human system (Respiratory and circulatory systems) Cell system Electrical system
Interactions	Interaction of forces (Magnets)	Interaction of forces (Frictional force, gravitational force, force in springs) Interaction within the environment
Energy	Energy forms and uses (Light and heat)	Energy forms and uses (Photosynthesis) Energy conversion

Source: CPDD (2007)

1.2.2 Science Curriculum Framework

The implementation of primary science education in Singapore is guided by the Science Curriculum Framework (CPDD, 2007), which is derived from the Policy Framework for the Teaching and Learning of Science. It encapsulates the thrusts of science education in Singapore of preparing students to be sufficiently adept as effective citizens and to be able to function in and contribute to an increasingly technologically-driven world.

Figure 1.1 shows a pictorial depiction of the framework. Central to the framework is the inculcation of the spirit of scientific inquiry which is founded on three domains of (a) knowledge, understanding and application, (b) skills and processes and (c) ethics and attitudes. The curriculum design seeks to enable students to view the study of science as meaningful and useful. Inquiry is thus grounded in knowledge, issues and questions that relate to the roles played by science in daily life, society and the environment.

The primary science curriculum seeks to nurture the student as the inquirer and the teacher as the leader of inquiry in the classroom. The design of the curriculum assumes that children are naturally curious and likely to enjoy science and value it as an important tool in their exploration of their natural and physical world. Teachers, on the other hand, facilitate the inquiry process and, through the learning environment which they create, encourage and challenge students to develop their sense of inquiry.

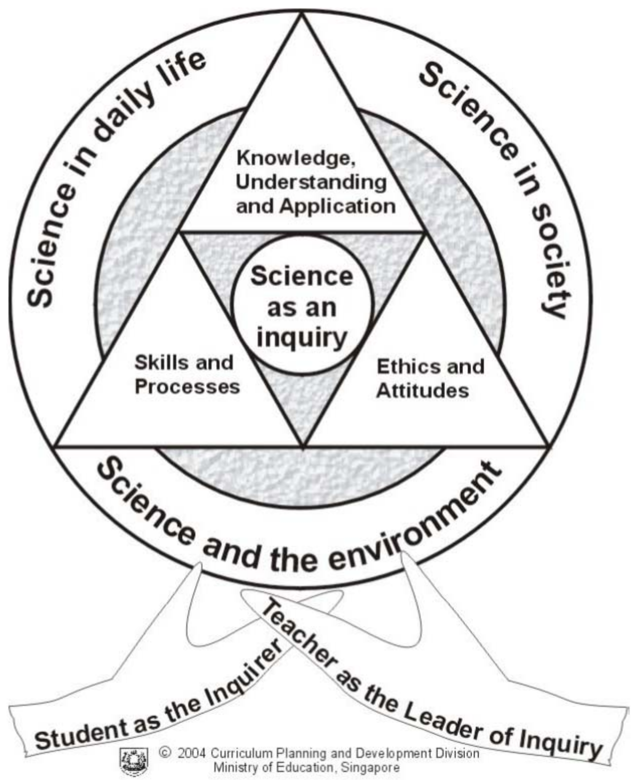

Figure 1.1 Science Curriculum Framework (Source: CPDD, 2007)

1.2.3 Teaching and Learning of Primary Science

The curriculum planning and development division under the Ministry of Education in Singapore advocates the teaching of science as inquiry. Primary science teachers are encouraged to make use of a variety of strategies to facilitate the inquiry process (CPDD, 2007).

Teaching of science as inquiry is not new. As early as the 1960s, Schwab (1962) urged science educators to stress the conceptions of science and how they change over time. He placed a premium on how scientists view the ideas (content) that they are developing and how these ideas shape what scientists do and say about the data that they collect. Since then, science educators have been advocating that learning with inquiry be placed at the core of science instruction in order to actively engage learners in the processes of science (AAAS, 1993; DeBoer, 1991; NRC, 2000).

According to the National Science Education Standards (NSES), inquiry is defined as "a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations and predictions; and communicating the results" (NRC, 1996, p. 23). Embedded in this definition are the five essential features of classroom inquiry articulated by the NSES document (NRC, 2000):

- Learners are engaged by scientifically-oriented questions.
- Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically-oriented questions.
- Learners formulate explanations from evidence to address scientifically-oriented questions.
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
- Learners communicate and justify their proposed explanations.

Inquiry lessons are described as partial when one or more of the five essential elements of inquiry are missing. For example, if the teacher demonstrates how something works rather than allowing students to discover it for themselves, then that lesson is regarded as partial inquiry. Lessons that vary in their level of direction are needed to develop students' inquiry abilities. Students will benefit most from experiences that vary between these two inquiry approaches.

To help primary science teachers to facilitate inquiry in the classroom, the primary science syllabus in Singapore has adapted the five essential features of inquiry-based teaching from the NSES (NRC, 1996) (CPDD, 2007). Table 1.2 shows the variations on each of the essential features of inquiry.

Table 1.2 Essential Features of Inquiry and Their Variations

Essential Features of Science as Inquiry	← More Less ←	Amount of Student Self-direction Amount of Guidance from		Less → More →
1. Question Students engage with an event, phenomenon or problem when they…	Pose a question	Select among questions	Sharpen or clarify question provided	Accept given question
2. Evidence Students give priority to evidence when they…	Determine what constitutes evidence and collect it	Are directed to collect certain data	Are given data and asked to analyse	Are given data and told how to analyse
3. Explanation Students construct explanations when they…	Formulate their own explanation after summarising evidence	Are guided in process of formulating explanation from evidence	Are given possible ways to use evidence to formulate explanation	Are provided with evidence
4. Connections Students evaluate their explanations when they…	Examine other resources and form links to explanations	Are directed toward sources of knowledge	Are given possible connections	Are provided with connections
5. Communication Students communicate and justify their explanations when they…	Form reasonable and logical argument to communicate explanations	Are coached in development of communication	Are provided guidelines for communication	Are given steps and procedure for communication

Adapted from Inquiry and the National Science Education Standards, National Research Council (2000).
Source: CPDD (2007)

1.3 Theoretical Framework

Students spend on an average about 20,000 hours in classrooms by the time they graduate from university (Fraser, 2001). Therefore, they have a stake in what happens to them in class and the perceptions of their experiences in the classrooms are of great significance.

Fraser (2001) also asserts having a positive classroom environment is a valuable goal in education. He adds that evidence has shown that the classroom environment strongly influences student outcomes and that it should not be ignored by those wishing to improve educational effectiveness. It is thus not surprising to see from the literature relating to learning environments research that a great amount of work has been undertaken in this area over the last few decades (Fraser, 2012).

Much of the work in the field of learning environments in the past 40 years can be traced back to Lewin's (1936) seminal work on field theory in which he recognised that both the environment and its interaction with personal characteristics of the individual play an important part in determining human behaviour. The now familiar Lewinian formula $B = f(P, E)$ stresses that both the person (P) and the environment (E) are powerful determinants of human behaviour (B). Following this train of thought, Murray (1938) brought to light the difference in perception between outside observers and those directly involved in the environment being studied and a needs–press model which allows the analogous representation of person and environment in common terms. Since then, the notion of person–environment fit has been elucidated in education by Stern (1970), who proposed that the degree of person–environment congruence is related to student outcomes. Also, Walberg (1981) has proposed a model of educational productivity in which the educational environment is one of nine determinants of student outcomes. Research specifically on classroom learning environments took off with the work of Walberg and Anderson (1968) and Moos (1974) which spawned many diverse research programs around the world (Fraser, 1994, 1998a, 2012).

The history of learning environments research resulted in the conceptualisation of a variety of validated and robust questionnaires that assess students' perceptions of their classroom learning environment. Not only are these questionnaires easily available, they are also economical, valid and widely applicable for assessing students' perceptions of their classroom environment. Several different instruments have been devised for assessing the classroom environment (Fraser, 1998b), including the Learning Environment Inventory (LEI), My Class Inventory (MCI), Questionnaire on Teacher Interaction (QTI), Individualised Classroom Environment Questionnaire (ICEQ), Classroom Environment Scale (CES), Science Laboratory

Environment Inventory (SLEI), What Is Happening In this Class? (WIHIC) and Constructivist Learning Environment Survey (CLES). Chapter 2 reviews in greater detail the literature relevant to these learning environment instruments.

The strongest tradition in past classroom environment research has involved investigation of associations between students' cognitive and affective learning outcomes and their perceptions of psychosocial characteristics of their classrooms. Fraser (2002) reports that the most common line of learning environment research in Asia, as in the case for Western research, involves associations between students' outcomes and their classroom environment perceptions. These studies have been conducted across various subjects and grade levels, with the use of numerous student outcomes measure and different learning environment questionnaires. These studies reveal the consistency of associations between student outcomes and the classroom environment.

From a researcher's point of view, I was interested in understanding the psychosocial learning environment that exists in primary science classrooms as well as the attitudes of students towards science. I was able to draw on the wide resource of assessment instruments that are available in the field of learning environments (Fraser, 1998b, 1998c). The learning environment scales for my study were chosen from the CLES and WIHIC questionnaires.

Taylor, Fraser and Fisher (1997) designed the Constructivist Learning Environment Survey (CLES) to enable researchers and teachers to assess the extent to which a classroom's environment is consistent with constructivist learning. The scales in the CLES were developed based largely on a psychosocial view of constructivist reform that focused on students as co-constructors of knowledge. In my study, only one of the five scales, Student Negotiation, was used.

Fraser, Fisher, and McRobbie (1996) developed the What Is Happening In this Class? (WIHIC) by combining modified versions of the most salient scales from a wide range of existing questionnaires with additional scales that accommodate contemporary educational concerns (Equity and Constructivism). The WIHIC measures a wide range of dimensions which are important in the present situation in classrooms. In my study, three of the seven scales from the WIHIC (Involvement, Investigation and Cooperation) were used.

In this study, a new scale, Connection, was also developed and included in the learning environment section of the questionnaire to measure the extent to which science lessons involve connections between what students have learned in science and their daily experiences.

My study also involved investigating students' attitudes to science. Thus, in addition to the selected scales from CLES and WIHIC for assessing the learning environment, my study also included two scales from Test of Science-Related Attitudes (TOSRA), which measures seven science-related attitudes among secondary students (Fraser, 1978). In my study, the two scales of Attitude to Scientific Inquiry and Enjoyment of Science Lessons were used to measure attitudes. For convenience, the learning environment scales and attitude scales were combined together to form a single questionnaire, the Science Learning Environment and Attitude Questionnaire (SLEAQ), with all scales having a common response format. The SLEAQ is described in greater detail in Section 3.3.

1.4 Purposes of the Study

The first step was to confirm the reliability and the validity of the SLEAQ for assessing classroom learning environments and student attitudes at the primary level in Singapore. The first research question was:

Research Question #1

> *Is a science learning environment and attitude questionnaire valid when used with primary science students in Singapore?*

To determine whether differences exist between students' perceptions of the actual and preferred science learning environment, the second research question was developed.

Research Question #2

Are there differences between students' perceptions of actual and preferred learning environments?

To determine whether students of different sexes perceive their learning environment differently and have different attitudes, the third research question was developed.

Research Question #3

Are perceptions of the learning environment and attitudes different for students of different sexes?

Finally, to determine whether there were associations between the learning environment and student outcome, the last research question was developed.

Research Question #4

Is there a relationship between students' perceptions of the learning environment and their attitudes?

1.5 Significance of the Study

The field of learning environment research has a long and illustrious history involving a variety of validated and robust questionnaires for assessing students' perceptions of their learning environments both in Western and Asian countries (Fraser, 2012).

Although the Singapore government has made education one of its priorities, overall the amount of educational research in Singapore has not been extensive. A review specifically of research on science learning environments conducted in Singapore reveals only a small number of studies that have been conducted with secondary students (Quek, Wong & Fraser, 2005; Wong & Fraser, 1996). Recently, Peer and Fraser (in press) investigated gender, grade-level and stream differences in the attitudes and learning perceptions of gifted primary science students.

There is a need to study the learning environment of primary science classrooms with the aim of improving teaching and learning practices. My research involving the development and use of a classroom learning environment questionnaire would not only complement the research previously completed and still being undertaken, but it would also provide a more complete picture of the process of science education in Singapore.

This study is significant in that it involved developing and validating the Science Learning Environment and Attitude Questionnaire (SLEAQ) which could be used in mainstream classrooms in the Singapore primary school context. I hope to be able to contribute to this field of learning environments by filling a gap involving the lack of instruments for use at the primary levels where teachers would be able to make use of it easily for investigating students' perceptions of their science inquiry learning environments and by using this as a basis for improving their teaching and classroom environments. In addition, as most of these questionnaires originated from Western countries, it could be worthwhile to develop new questionnaires that tap into the nuances and uniqueness of Asian classrooms.

1.6 Overview of the Thesis

The thesis comprises five chapters. This first chapter introduces the study by providing a description of the primary science education system in Singapore. Also provided are the background and the purpose of the research. The chapter also discusses the significance of the study.

Chapter 2 reviews pertinent literature that links the present study to the work of previous researchers who have contributed to the field of learning environments. This chapter highlights research developments and findings in learning environments undertaken over the past 40 years, including instrument applications and research in Singapore.

Chapter 3 provides information about the procedural aspects of the present study, including the research design, the sample of participants involved, the development of the instruments used, and details of the pilot study designed to field test the instruments. This chapter also includes a discussion of data-collection procedures, as well as the methods of data analysis chosen to answer each research question.

Chapter 4 reports analyses and results for each research question of the study. Specifically, it provides evidence for the reliability and the validity of the Science Learning Environment and Attitude Questionnaire (SLEAQ) for use in primary science classrooms in Singapore. Analyses included factor analyses, scale internal consistency reliability (Cronbach alpha coefficient), and ANOVA results for the ability of scales to differentiate between students in different classrooms. Also reported in this chapter are the results using one-way MANOVA to examine differences in students' perceptions of their actual and preferred classroom and between male and female students. Finally, the results are reported for simple correlation and multiple regression analyses undertaken to investigate associations between students' attitudes and the nature of the learning environment.

Chapter 5 concludes the thesis with a summary of the present study. This chapter provides information regarding the implications of the findings of the study, as well as the constraints and limitations of the study. Recommendations for future research are also included in this chapter.

Chapter 2

REVIEW OF RELATED LITERATURE

2.1 Introduction

The major purposes of the present study were to validate a modified learning environment and attitude questionnaire specific to primary science classrooms in Singapore, investigate differences in students' perceptions of actual and preferred classroom learning environment, examine sex differences in learning environment perceptions and attitudes to science, and investigate associations between students' attitudes and the nature of the classroom learning environment.

This chapter reviews literature related to the study and is organised under the following sections:

- Field of Classroom Learning Environment (Section 2.2)
- Instruments for Assessing Classroom Learning Environment (Section 2.3)
  - Learning Environment Inventory (LEI) (Section 2.3.1)
  - Classroom Environment Scale (CES) (Section 2.3.2)
  - Individualised Classroom Environment Questionnaire (ICEQ) (Section 2.3.3)
  - My Class Inventory (MCI) (Section 2.3.4)
  - College and University Classroom Environment Inventory (CUCEI) (Section 2.3.5)
  - Questionnaire on Teacher Interaction (QTI) (Section 2.3.6)
  - Science Laboratory Environment Inventory (SLEI) (Section 2.3.7)
- Development, Validation and Use of the Constructivist Learning Environment Survey (CLES) (Section 2.4)
- Development, Validation and Use of the What Is Happening In this Class? (WIHIC) Questionnaire (Section 2.5)
- Research in the Field of Learning Environment (Section 2.6)
  - Associations Between Classroom Environment and Student Outcomes (Section 2.6.1)

- Differences Between Students' and Teachers' Perceptions of Actual and Preferred Environment (Section 2.6.2)
- Sex Differences in Learning Environment Perceptions (Section 2.6.3)
- Combining Quantitative and Qualitative Research Methods (Section 2.6.4)

- Students' Attitudes Towards Science (Section 2.7)
  - Development, Validation and Use of the Test of Science-Related Attitudes (TOSRA) (Section 2.7.1)
  - Associations Between the Classroom Learning Environment and Attitudes Towards Science (Section 2.7.2)
- Summary (Section 2.8).

2.2 Field of Classroom Learning Environment

The word 'environment' has numerous meanings. In the context of the classroom, two common aspects of environment exist: the physical environment (which includes the material setting of the classroom, such as the furniture, lightning and all objects in the classroom); and the human environment (which involves the students and the teachers and their interactions with each other).

Fraser (1998a) defines the learning environment as referring to "the social, psychological, and pedagogical contexts in which learning occurs and which affect student achievement and attitudes" (p. 3) and this environment involves the shared perceptions of the students and sometimes the teachers within that environment. Because students would have spent on an average about 20, 000 hours in classrooms by the time they graduate from university (Fraser, 2001), what happens in these classrooms and students' reactions and perceptions of their school experiences are of great importance and are significant. It is indeed worthwhile to find out what could be improved in the environment within a classroom as there is strong evidence that effective learning is related to a positive classroom environment (Brophy & Putnam, 1979).

Over the past 40 years, the considerable progress that has been made in conceptualising, measuring and investigating this aspect of the classroom is reflected in historically-significant books (Fraser, 1986; Fraser & Walberg, 1991; Moos, 1979; Walberg, 1979), recent books (Fisher & Khine, 2006; Goh & Khine, 2002; Khine & Fisher, 2003), literature reviews (Fraser, 1994, 1998a, 2007, 2012), the American Educational Research Association's Special Interest Group (SIG) on Learning Environments which began in mid-1980s, the initiation in 1998 of Kluwer/Springer's *Learning Environments Research: An International Journal* and the initiation of a book series entitled *Advances in Learning Environments Research* (Aldridge & Fraser, 2008).

The starting point for the area of learning environment originated in the field of the social sciences with Lewin (1936) expressing that human behaviour (*B*) is a function of the person (*P*) and the environment (*E*) through a formula $B = f(P, E)$. Murray (1938) followed Lewin's approach by proposing a needs–press model which allows the analogous representation of person and environment in common terms. Murray introduced the term *alpha press* to describe the environment as perceived by a detached observer and the term *beta press* to describe the environment as observed by the participants themselves (Fraser, 1998a).

The approach of using students' and teachers' perceptions to study educational environments can be contrasted with the external observer's systematic coding of classroom communication and events (Brophy & Good, 1986). Describing the classroom environment through the actual participants is advantageous as observers might miss certain information or consider certain information as unimportant. In addition, students would have been in the class long enough to form accurate judgements of their learning environment.

All of the early instruments assessed students' perceptions of the classroom as a single entity. Stern, Stein and Bloom (1956) extended Murray's notion of beta press into *private* beta press and *consensual* beta press. Perception scores obtained from individual students (private beta press), as compared with the average of the environment scores of all students within the same class (consensual beta press), could, and often do, differ from each other. The distinction between private and consensual press did not take root when designing new questionnaires until the development of the Science Laboratory Environment Inventory (SLEI). Fraser

(1998a) explains that the choice of level or unit of statistical analysis is important because:

> Measures having the same operational definition can have different substantive interpretations with different levels of aggregation; relationships obtained using one unit of analysis could differ in magnitude and even in sign from relationships obtained from using another unit; the use of certain units of analysis (e.g., individuals when classes are the primary sampling units) violates the requirement of independence of observations and calls into question the results of any statistical significance tests because an unjustifiably small estimate of the sampling error is used; and the use of different units of analysis involves the testing of conceptually different hypotheses. (p. 530)

The first learning environment questionnaire for use in the educational setting, the Learning Environment Inventory (LEI), was developed in the 1960s by Herbert Walberg as part of his research and the evaluation of the activities in Harvard Physics Project (Walberg & Anderson, 1968). At the same time, Rudolf Moos developed the first of his social climate scales for use in psychiatric hospitals and correctional institutions, which later resulted in the development of the Classroom Environment Scale (CES) (Moos, 1974, 1979; Moos & Trickett, 1974; Trickett & Moos, 1973).

The LEI, CES and all the other instruments that followed were modeled on Moos' (1974) three basic categories for classifying human environments: Relationship Dimensions (which identify the nature and intensity of personal relationships within the environment and assess the extent to which people are involved in the environment and support and help each other), Personal Development Dimensions (which assess basic directions along which personal growth and self-enhancement tend to occur) and System Maintenance and System Change Dimensions (which involve the extent to which the environment is orderly, clear in expectations, maintains control and is responsive to change) (Fraser, 1998a). Table 2.1 in Section 2.3 shows how the scales in each of nine historically-important and contemporary classroom learning environment instruments fall into Moos's dimensions. The important pioneering work of both Walberg and Moos on perceptions of classroom environment led to the development of many programs and a lot of other research, bringing the field of learning environment to greater heights and resulting in the conceptualisation, development and validation of several questionnaires which are discussed in the following sections.

2.3 Instruments for Assessing Classroom Learning Environment

A hallmark of the field of learning environments has been the development of a variety of questionnaires to assess students' perceptions of their classroom learning environments (Fraser, 1998b). These questionnaires have been validated and used by researchers, teachers and students in many different countries and at different grade levels (Goh & Fraser, 1998, 2000; Khoo & Fraser, 2008; Quek, Wong & Fraser, 2005). They have also been translated into various languages, including Indonesian (Fraser, Aldridge & Adolphe, 2010; Margianti, Fraser, & Aldridge 2001a, 2001b), Chinese (Aldridge & Fraser, 2000; Aldridge, Fraser & Huang, 1999), Korean (Kim, Fisher & Fraser, 2000; Lee, Fraser & Fisher, 2003), Arabic (Afari, Aldridge, Fraser & Khine, 2013; MacLeod & Fraser, 2010) and Spanish (Allen and Fraser, 2007; Peiro & Fraser, 2009). Not only are these questionnaires easily available, but they are also economical, valid and widely applicable for assessing students' perceptions of their classroom environment.

This section describes seven of nine historically-significant and contemporary classroom environment instruments that have been used to assess the psychosocial perceptions of classroom learning environments among elementary, secondary and tertiary students. The Constructivist Learning Environment Survey (CLES) and What Is Happening In this Class? (WIHIC) are reviewed in greater detail in Sections 2.4 and 2.5 as they were used as a source of scales for my study. Table 2.1 provides an overview of the questionnaires and indicates for each the name of the instrument, its developers, intended level of usage, number of items per scale, the name of each scale, and how each scale aligns with Moos's three dimensions.

Table 2.1 Overview of Scales Contained in Some Classroom Environment Instruments (LEI, CES, ICEQ, CUCEI, MCI, QTI, SLEI, CLES and WIHIC)

Instrument	Level	Items per Scale	Scales Classified According to 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 Affiliation Teacher Support	Task Orientation Competition	Order and Organisation Rule Clarity Teacher Control Innovation
Individualised Classroom Environment Questionnaire (ICEQ)	Secondary	10	Personalisation Participation	Independence Investigation	Differentiation
College and University Classroom Environment Inventory (CUCEI)	Higher Education	7	Personalisation Involvement Student Cohesiveness Satisfaction	Task Orientation	Innovation Individualisation
My Class Inventory (MCI)	Elementary	6–9	Cohesiveness Friction Satisfaction	Difficulty Competitiveness	
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 this Class? (WIHIC)	Secondary	8	Student Cohesiveness Teacher Support Involvement	Investigation Task Orientation Cooperation	Equity

Source: Fraser (2012)

2.3.1 Learning Environment Inventory (LEI)

The LEI, as mentioned earlier in Section 2.2, was developed and validated in the late 1960s by Walberg. This was in conjunction with the evaluation and research related to the Harvard Project Physics (Fraser, Anderson & Walberg, 1982; Walberg & Anderson, 1968). The LEI was used to assess the actual environment of predominantly ‘teacher-centred’ classrooms. Preferred or personal forms were not considered during the development of the LEI.

The final version was made up of 15 scales with seven items per scale, resulting in a total of 105 items, which are descriptive of typical school classes. Students express the degree of agreement or disagreement with each item using the four response alternatives of Strongly Disagree, Disagree, Agree and Strongly Agree. The scoring direction (or polarity) is reversed for some items. A typical item in the Cohesiveness scale is “All students know each other very well” and in the Speed scale is “The pace of the class is rushed”.

2.3.2 Classroom Environment Scale (CES)

The CES was developed by Rudolf Moos at Stanford University (Moos & Trickett, 1974, 1987; Trickett & Moos, 1973) as the result of a comprehensive program of research involving perceptual measures of a variety of human environments, including psychiatric hospitals, prisons, university residences and work surroundings (Moos, 1974). The final published version contains a total of 90 items in nine scales: Involvement, Affiliation, Teacher Support, Task Orientation, Competition, Order and Organisation, Rule clarity, Teacher Control and Innovation (10 items per scale). The response format in each scale is either True or False and the scoring direction is reversed for many items. Typical items in the CES are “The teacher takes a personal interest in the students” (Teacher Support) and “There is a clear set of rules for students to follow” (Rule Clarity). Published materials include a test manual, a questionnaire, an answer sheet and a transparent hand scoring key.

The CES had been used to investigate associations between classroom environment and outcome measures such as academic achievement, attitudes (Fraser & Fisher, 1982b), absences and grades (Moos & Moos, 1978), and inquiry skills (Fisher & Fraser, 1983b; Fraser & Fisher, 1982b, 1982c). An interesting area of learning environment research that was pioneered using the actual and preferred forms of the CES was conducted in Australia by Fraser and Fisher (1983a) when they brought the two separate areas of person–environment fit and classroom environment studies together. Their study involved 2,175 students in 116 grades eight and nine science classes and investigated the person–environment fit hypothesis of whether the relationship between achievement and actual classroom environment varies with the environment preferences of the class. Half of the students completed the actual form of the CES and the other half completed the preferred form.

Two cognitive outcome measures from the Test of Enquiry Skills (Fraser, 1979) and one affective outcome measure from the Test of Science-Related Attitudes (Fraser, 1981) were administered using a pretest–posttest design. Also, student general ability was measured near the middle of the year. The class mean was chosen as the unit of analysis because the CES scales reflect wording designed for measuring class-level environment characteristics. Findings suggested that actual–preferred congruence at the class level could be as important as the nature of actual classroom environment in predicting class achievement of important cognitive and affective aims. Higher student achievement was found for classes whose students had a higher preference for a particular environment scale than in classes whose students had a lower preference for that scale.

2.3.3 Individualised Classroom Environment Questionnaire (ICEQ)

The ICEQ was initiated to assess individualised, open and inquiry-based classrooms from conventional ones (Fraser, 1990; Rentoul & Fraser, 1979). However, the instrument also proved to be useful in measuring general classroom environment when used in conjunction with the LEI or CES (Fraser & Fisher, 1982b). The final published version (Fraser, 1990; Fraser & Butts, 1982) contains 50 items in the five scales of Personalisation, Participation, Independence, Investigation and Differentiation (10 items per scale). Each item has the five frequency response alternatives of Almost Never, Seldom, Sometimes, Often and Very Often. The scoring direction is reversed for many of the items. Typical items are: “The teacher considers students' feelings" (Personalisation) and "Different students use different books, equipment and materials" (Differentiation). The ICEQ has separate actual and preferred versions and a progressive copyright arrangement which allows purchasers the right to make unlimited number copies of the questionnaires and response sheets.

2.3.4 My Class Inventory (MCI)

The MCI is a simplified version of the LEI with the five scales of Satisfaction, Friction, Competitiveness, Difficulty and Cohesiveness. It is appropriate for use by students aged 8–12 years (Fisher & Fraser, 1981; Fraser, Anderson & Walberg, 1982; Fraser & O'Brien, 1985). Although the MCI is appropriate for use at the primary level, because of the low reading levels of its items, it has also been found to be useful with students in the junior high school, especially for those who might experience reading difficulties with other instruments.

The MCI was made easier by simplifying the item wording to enhance readability for younger children. It also contains only five of the LEI's original 15 scales, with the final form containing 38 items (long form) and 25 items (short form), so as to minimise fatigue while answering the questionnaire. The LEI's four-point responses format has been reduced to a two-point (Yes–No) response format and, lastly, students can answer directly onto the questionnaire itself to reduce errors that could arise from the transferring of responses to a separate answer sheet. These features make the questionnaire economical in terms of the time required for administrating and testing. Typical items in the MCI are "Pupils seem to like my class" and "My class is fun". It also contains reverse-scored items, such as "Some pupils are not happy with my class".

Several studies have explored how science and mathematics teachers have made use of the MCI to assess and improve the environments of their own classrooms. One early study was conducted by Fraser and O'Brien (1985) who validated the short form of the MCI with a sample of 758 Grade 3 students in 32 classes in eight schools located in the Sydney metropolitan area. Both the actual and preferred forms of the short form of the MCI had satisfactory reliability for scales containing only five items each. In a separate study, a Grade 6 elementary teacher with 26 lower-ability students at a co-educational government school in a suburb of Sydney used actual and preferred forms of the MCI to guide attempts to improve the environment of her classroom. The teacher incorporated five steps in order to make improvements: (1) assessment using the preferred form of the MCI first before administering the actual form, (2) feedback in the form of graphical profiles to compare any differences between preferred and actual environment scores, (3) reflection and discussion with colleagues prior to changing the classroom environment in terms of the MCI's scales before deciding to introduce an intervention aimed at reducing the level of Competitiveness and increasing the level of Cohesiveness, (4) intervention consisting of a variety of strategies to change the classroom environment over a period of approximately two months, and (5) reassessment involving readministering the actual form of the MCI at the end of the intervention. The results from the case study indicated that, during the time of intervention, a statistically significant reduction in actual–preferred discrepancy occurred for the scales of Competitiveness and Cohesiveness (i.e., the two scales on which the teacher had attempted to promote change), but nonsignificant changes occurred on the other three MCI scales.

The MCI was used with a large sample of mathematics students in Brunei. Majeed et al. (2002) used an English version of the MCI with 1,565 lower secondary mathematics students to investigate the learning environment and its association with student satisfaction. The longer version of the MCI was modified for the Bruneian context by using only three scales – Cohesiveness, Difficulty and Competitiveness. A satisfactory factor structure was found for the three-scale version of the MCI. These researchers reported sex differences in learning environments (with boys having slightly more positive perceptions) and statistically significant associations between students' satisfaction and the nature of the classroom environment for most MCI scales.

2.3.5 College and University Classroom Environment Inventory (CUCEI)

The CUCEI was developed for assessing the classroom environment of small groups of students (up to 30) at the college and the university level (Fraser & Treagust, 1986; Fraser, Treagust & Dennis, 1986). The final version has 49 items in seven scales, namely, Personalisation, Involvement, Student Cohesiveness, Satisfaction, Task

Orientation, Innovation and Individualisation (seven items per scale). Many scales in the CUCEI overlap with other and more recent instruments, particularly the WIHIC. Each item has four possible responses: Strongly Agree, Agree, Disagree and Strongly Disagree. The polarity is reserved for half of the items. Typical items are “Activities in this class are clearly and carefully planned” (Task Orientation) and “Teaching approaches allow students to proceed at their own pace” (Individualisation). Like other instruments, the CUCEI has both actual and preferred forms for students and teachers to use.

Fraser, Williamson and Tobin (1987) used the CUCEI successfully with 536 students in 45 classes to evaluate some alternative high schools and found that these students perceived their classes as having greater Involvement, Satisfaction, Innovation and Individualisation when compared to some control groups. When Logan, Crump and Rennie (2006) used the CUCEI in computing classrooms in New Zealand, they found that its psychometric performance was not ideal.

2.3.6 Questionnaire on Teacher Interaction (QTI)

The QTI was developed in the Netherlands to measure the nature and quality of student–teacher interaction in the classroom (Creton, Hermans & Wubbels, 1990; Wubbels & Brekelmans, 2005; Wubbels, Brekelmans & Hooymayers, 1991; Wubbels & Levy, 1993). Unlike other classroom environment instruments, the QTI draws upon a theoretical model of proximity (cooperation–opposition) and influence (dominance–submission). The QTI was developed to assess student perceptions of eight aspects of teacher behaviour: Leadership, Helpful/friendly, Understanding, Student responsibility/freedom, Uncertain, Dissatisfied, Admonishing and Strict. Each item has a five-point response scale ranging from Never to Always. Typical items are “She/he gives us a lot of free time” (Student Responsibility and Freedom behaviour) and “She/he gets angry” (Admonishing behaviour).

Although research with the QTI began at the senior high school level in the Netherlands, it has been cross-validated at various grade levels in the USA (Wubbels & Levy, 1993), Australia (Fisher, Henderson & Fraser, 1995), Singapore (Goh & Fraser, 1996; Quek, Wong & Fraser, 2005), Brunei (Riah, Fraser & Rickards, 1997) and India (Koul & Fisher, 2005). It has also undergone modifications since its inception. For example, Goh and Fraser (1996) developed and validated a more economical 48-item version of the QTI and Fisher and Cresswell (1998) modified the QTI to form the Principal Interaction Questionnaire (PIQ) which assesses teachers' or principals' perceptions of the same eight dimensions of a principal's interaction with teachers. The QTI has also undergone several translations and cross-validations in: Standard Malay for use with 3,104 students in 136 elementary school classrooms in Brunei (Scott & Fisher, 2004); Korean by Lee, Fraser and Fisher (2003) among 439 science students and by Kim, Fisher and Fraser (2000) among 543 students; Bahasa Indonesian by Fraser, Aldridge and Adolphe (2010) with a sample of 567 Australian and 594 Indonesian students in 18 secondary science classes; and by Fraser, Aldridge and Soerjaningsih (2010) with a sample of 422 university students.

The QTI has been extensively used in a number of different contexts, including the professional development of teachers (Fisher & Cresswell, 1998), a cross-national study of the perceptions of interpersonal teacher behaviour in secondary science classrooms (Fisher, Goh, Wong & Rickards, 1997), the relationships between science students' perceptions of their teachers' interpersonal behaviour, students' cultural background and gender (Rickards, 1998) and the investigation of sex differences in biology students' perceptions of teacher–student relationships (Henderson, Fisher & Fraser, 1995).

2.3.7 Science Laboratory Environment Inventory (SLEI)

The SLEI was designed specifically for science laboratory classes to obtain feedback about students' views of laboratory settings and the impact of laboratory classes on student outcomes (Fraser, Giddings & McRobbie, 1995; Fraser & McRobbie, 1995; Fraser, McRobbie & Giddings, 1993).

The SLEI is appropriate for students at the upper-secondary and higher-education levels and it is intended for use in situations in which a separate laboratory class exists. Like the MCI, the SLEI has 5 scales (each with 7 items): Student Cohesiveness, Open-endedness, Integration, Rule Clarity and Material Environment. The frequency response alternatives for each item are Almost Never, Seldom, Sometimes, Often and Very Often. Typical items are “I use the theory from my regular science class sessions during laboratory activities” (Integration) and “We know the results that we are supposed to get before we commence a laboratory activity” (Open-Endedness). The Open-Endedness scale was included because of the importance of open-ended laboratory activities often claimed in the literature (Hodson, 1988). The scoring direction is reversed for approximately half of the items and these items include “I find that the laboratory is crowded when I am doing experiments” (Material Environment) and “I have little chance to get to know other students in this laboratory class” (Student Cohesiveness). Besides having forms which measure perceptions of actual and preferred environments, the SLEI has a personal version (involving a student’s perception of his/her own role in the classroom) in contrast to other instruments which exist only in a class version (involving a student’s perceptions of the class as a whole) (Fraser, Giddings & McRobbie, 1995).

The SLEI was field-tested and validated simultaneously with a sample of over 5,447 students in 269 classes in six different countries (the USA, Canada, England, Israel, Australia and Nigeria) and cross-validated with 1,594 Australian students in 92 classes (Fraser & McRobbie, 1995) and 489 senior high school biology students in Australia (Fisher, Henderson & Fraser, 1997). A slightly modified version (the word ‘chemistry’ was used instead of ‘science’) of the SLEI was cross-validated in Singapore by Wong and Fraser (1996) with 1,592 grade 10 chemistry students and by Quek, Wong and Fraser (2005) with 497 final-year gifted and non-gifted chemistry students.

Fraser and Lee (2009) translated the SLEI into the Korean language for use in assessing the laboratory classroom environments of three streams (science-independent, science-oriented and humanities) using a sample of 439 high school students in Korea. The study revealed that 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.

In the USA, Lightburn and Fraser (2007) worked with a sample of 761 high school biology students in 25 classes to evaluate the effectiveness of using anthropometry activities in the classrooms, whereas Martin-Dunlop and Fraser (2008) used selected SLEI scales for assessing students' perceptions of laboratory learning environments. In each of these cases, the SLEI was found to be a valid, reliable and useful instrument for measuring student perceptions.

2.4 Development, Validation and Use of the Constructivist Learning Environment Survey (CLES)

Whereas Section 2.3 gave a relatively brief overview of seven classroom learning environment instruments listed in Table 2.1, this section and Section 2.5 provide greater detail about the last two questionnaires, namely, the CLES and WIHIC. This is because, in my study, I used scales from these two instruments, together with two scales from TOSRA and a scale developed for the purpose of this study, to produce a modified learning environment and attitude questionnaire that was suitable for evaluating the primary science classrooms in my research.

Constructivists view learning as a cognitive process in which an individual tries to make sense of the experiential world, based on the individual's existing knowledge by a process of active negotiation and consensus building. The CLES was designed specifically to assist researchers and teachers to assess the degree to which a particular classroom's environment is consistent with constructivist epistemology, and to also assist teachers in reflecting on their epistemological assumptions and reshaping their teaching practice (Fraser, 2002).

According to Taylor, Fraser and Fisher (1997), the original CLES (Taylor & Fraser, 1991) was based largely on a psychosocial view of constructivism reform that focuses on students as co-constructors of knowledge. However, the design of the questionnaire did not meet the needs of the cultural context framing the classroom environment and its theoretical framework supported only a weak program of constructivist reform. The original CLES was subsequently redesigned to incorporate a critical theory perspective on the cultural framing of the classroom learning environment (Taylor, Dawson & Fraser, 1995; Taylor, Fraser & Fisher, 1997; Taylor, Fraser & White, 1994).

The revised CLES was designed to obtain measures of students' perceptions of the frequency of occurrence of five key dimensions of a critical constructivist learning environment: Personal Relevance, Uncertainty, Critical Voice, Shared Control and Student Negotiation. Modifications were made both to the content and the format of the CLES. Items which had wording which was conceptually complex were removed and the use of negatively-worded items was minimised. The traditional cyclic format for arranging items in learning environment questionnaires was abandoned and, instead, items were grouped together in their respective scales with a 'user-friendly' title. A prompt, such as "In this class…", was also included to guide students in their thinking. The instrument is made up of a total of 30 items, with six items in each of the five scales. The frequency response alternatives are Almost Always, Often, Sometimes, Seldom and Almost Never. Table 2.2 provides a description of each scale and shows a sample item to clarify the classroom dimension that each scale seeks to assess for the revised version of the CLES.

When the new CLES was trialled across several countries and used in various contexts, it was found to be valid and reliable. In an evaluation of an urban systemic reform initiative in the USA, the CLES was used with a sample of approximately 1,600 students in 120 Grade 9–12 science classes in Dallas, Texas. Using Cronbach's alpha coefficient, relatively high internal consistency reliability values, ranging from 0.61 to 0.89 for the different CLES scales, were obtained. A principal components factor analysis was performed on the data to confirm the *a priori* structure of the CLES scales. However, analysis of the data also painted a disappointing picture in terms of a lack of success in achieving constructivist-oriented reform of science education (Dryden & Fraser, 1996).

Nix, Fraser and Ledbetter (2005) reported the validity and reliability of a modified version of the CLES, the CLES-CS, or the comparative student version, when it was administered to 1,079 students in 59 classes in north Texas. Students were asked to compare the degree to which they felt that the principles of constructivism had been implemented in the classes taught by teachers of the Integrated Science Learning Environment program with all of their other teachers. Principal components factor analysis with varimax rotation and Kaiser normalisation confirmed the *a priori* structure of the CLES-CS, with all except four items having a factor loading of at least 0.40 on its own scale and less than 0.40 on all other scales, and with a total of 45.5% of the variance being accounted for. Alpha reliabilities for different CLES scales ranged from 0.87 to 0.93 when the class mean was used as the unit of analysis, and all CLES scales were capable of differentiating significantly between the perceptions of students in different classes. The evaluation of this program revealed that the students of these teachers perceived their classrooms more favourably than did the students of the other teachers.

Table 2.2 Description and Sample Item for Each Scale in CLES

Scale Name	Description	Sample Item
Personal Relevance	This scale focuses on the connectedness of school science to students' out-of-school experiences, and with making use of students' everyday experiences as a meaningful context for the development of students' scientific and mathematical knowledge.	I learn how science can be part of my out-of-school life.
Uncertainty	This scale assesses the extent to which opportunities are provided for students to experience scientific knowledge as arising from theory-dependent inquiry involving human experience and values, and as evolving, non-foundational, and culturally and socially determined.	I learn about the different sciences used by people in other cultures.
Critical Voice	This scale examines the extent to which a social climate has been established in which students feel that it is legitimate and beneficial to question the teacher's pedagogical plans and methods, and to express concerns about any impediments to their learning.	It's OK for me to question the way I'm being taught.
Shared Control	This scale is concerned with students being invited to share with the teacher control of the learning environment, including the articulation of learning goals, the design and management of learning activities, and the determination and application of assessment criteria.	I help the teacher to decide which activities I do.
Student Negotiation*	This scale assesses the extent to which opportunities exist for students to explain and justify to other students their newly developing ideas, to listen attentively and reflect on the viability of other students' ideas and subsequently, to reflect self-critically on the viability of their own ideas.	Other students ask me to explain my ideas.

Adapted from Aldridge, Fraser, Taylor & Chen (2000)
* This scale was used in my study.

The CLES also has been used in South Africa, where learning environment research is just emerging. Aldridge, Fraser and Sebela (2004) conducted a large-scale study involving teacher action research in which the English version of the CLES was administered to 1,864 students in 43 Grade 4–9 classes. The study not only supported the reliability and factorial validity of the CLES for this population, but it also led to some improvements in the constructivist orientation of classrooms during a 12-week intervention.

The CLES has also been used in Singapore, although not as extensively. Wilks (2000) expanded and modified the CLES for use among students studying English (a subject called General Paper) in junior colleges in Singapore. The modified version, termed GPCLES, contained two additional scales relevant to the teaching of general paper called Political Awareness (reflecting Habermas's notion of emancipatory interest and assessing the extent to which students analyse causes of social injustice and advocate political reform) and Ethic of Care (the degree of emotional warmth in the classroom). The questionnaire displayed good factorial validity and internal consistency reliability when administered to 1,046 students in 48 classes in junior colleges.

The use of the CLES has been wide and it has undergone translations into various languages and administered to students in various countries. Aldridge, Fraser, Taylor and Chen (2000) validated and used English and Chinese versions of the CLES in high school science classrooms in Australia and Taiwan. In this cross-national study, the original English version was administered to 1,081 science students in 50 classes in Australia, while the new Chinese version was administered to 1,879 science students in 50 classes in Taiwan. The same five-factor structure emerged for the CLES in the two countries and scale reliabilities were similar. It was also reported that the Australian classes were perceived as being more constructivist than Taiwanese classes (especially in terms of Critical Voice and Student Negotiation).

The CLES has also been translated to the Korean language for use in Korea. Kim, Fisher and Fraser (1999) investigated the extent to which a new general science curriculum, reflecting a constructivist view, had influenced the classroom learning environment in Grade 10 science using the Korean version of the CLES. Other objectives of their study were to investigate whether the Korean version of CLES was valid and reliable and useful for identifying differences between students' perceptions of their actual and preferred learning environment and to determine associations between students' perceptions of the constructivist learning environment and their attitudes to science. The CLES was administered to 1,083 students and 24 science teachers in 12 different schools. One class of Grade 10 students and one class of Grade 11 students were sampled at each school. The numbers of boys and girls were almost the same in each local area and at each grade level. All scales of the Korean version of the CLES displayed satisfactory internal consistency. It was also found that each CLES scale differentiated significantly ($p<0.01$) between classes and that the eta^2 statistic, representing the proportion of variance explained by class membership, ranged from 0.05 to 0.13. These figures were relatively low and suggested that the learning environment of different science classes was relatively similar in Korea. Results also revealed statistically significant relationships between classroom environment and students' attitudes to science, that Grade 10 students perceived their environment as more constructivist than did Grade 12 students for most scales except Uncertainty, and that grade-level differences were statistically significant ($p<0.01$) for the three scales of Personal Relevance, Shared Control and Student Negotiation.

In another investigation of science classroom environments in Korea, Lee and Fraser (2001) focused on two aspects, namely, constructivism and the interaction pattern between students and teachers. Their study made use of the CLES and QTI after undertaking a rigorous translation procedure. Analyses of the survey data suggested that the Korean version of the CLES had satisfactory reliability and validity for all the scales when used in Korean high schools. It was found that science lessons 'sometimes' conveyed the notions of constructivism and that there was active implementation of constructivism in practice by teachers. The survey results also replicated the study by Kim, Fisher and Fraser (1999) and provided further support for the reliability and validity of CLES in Korea.

The CLES was also modified and translated into Spanish for use by Peiro and Fraser (2009). The English and Spanish versions were administered to 739 grade K–3 science students in Miami, USA and analyses of the data supported the validity of the both modified versions when used with these young children. Strong and positive associations were found between students' attitudes and the nature of the classroom environment, and a three-month classroom intervention led to large and educationally-important changes in classroom environment.

Spinner and Fraser (2005) used the CLES with two separate samples of 53 and 66 fifth-grade students undertaking an innovative mathematics program called the Class Banking System (CBS) in Florida. As well as cross-validating the CLES, the study also revealed that students who had undergone the CBS program experienced more favourable pre–post changes on most dimensions of the CLES when compared with students who did not.

In Canada, Roth (1998) also conducted a small-scale study in which the CLES was used as a tool to bring about reform in a science department in a private high school over a period of three years. The reform, which consisted of a change to student-centred open-inquiry science classrooms involved two classes of Grade 8 students (*N*=43) taught by the same teacher. The students were monitored in terms of their perceptions of their learning environment and their cognitive achievement. Using a combined quantitative and qualitative approach, Roth concluded that a mix of using the CLES, videotaped lessons, student interviews and test results was crucial for the teachers and researcher seeking to understand the complex nature of classroom learning environments.

Especially because constructivism focuses on the whole person and not just on a select aspect of his or her existence, the CLES is an appropriate instrument for measuring how learners perceive their environment. In my study, I used one of the five scales from CLES which was centrally relevant (namely, Student Negotiation) and modified this scale as described in greater detail in Chapter 3, Section 3.3.1. The wide use of the CLES in various past studies affirmed its validity as well as its convenience as an easy tool to use. Because its validity has been established in all previous studies, I felt that I could use it with confidence in my study.

2.5 Development, Validation and Use of the What Is Happening In this Class? (WIHIC) Questionnaire

Fraser, Fisher and McRobbie (1996) developed the What Is Happening In this Class? (WIHIC) questionnaire, which incorporates salient scales from a wide range of existing learning environment instruments, together with additional scales of current educational concern (e.g. Equity). Just like the SLEI, the WIHIC has a separate class form and personal form. The class form measures a student's perception of the class as a whole, while the personal form measures a student's perception of his/her role in the classroom.

The original version of the WIHIC had 90 items (nine scales, 10 items per scale) and it was field-tested and fine-tuned to form the second version which contains 80 items in eight scales, namely, Student Cohesiveness, Teacher Support, Autonomy/Independence, Involvement, Investigation, Task Orientation, Cooperation and Equity (10 items per scale). This second version of the WIHIC was field-tested by Aldridge, Fraser and Huang (1999) with junior high school science classes in Australia and Taiwan, with the Australian sample of 1,081 students in 50 classes responding to the English version and the Taiwanese sample of 1,879 students in 50 classes responding to the Chinese version. This led to the final form of the WIHIC containing seven eight-item scales that is commonly used in current studies. Table 2.3 provides a scale description and a sample item for each scale for the final version of the WIHIC.

Like the SLEI, the WIHIC has the five possible frequency responses of Almost Never, Seldom, Sometimes, Often and Almost Always. However, unlike the SLEI, all the WIHIC items are positively worded, as research has revealed that reverse scoring can give rise to confusion and low reliability (Barnette, 2000).

The WIHIC has been comprehensively validated in a large-scale cross-national study by Aldridge, Fraser and Huang (1999), who made use of the 70-item questionnaire, along with an attitude scale, to investigate science classroom environments in Taiwan and Australia. The data collected using the questionnaires were analysed to provide information regarding the reliability and validity of the questionnaires in each country, and to identify differences and similarities between students' perceptions in each country.

Table 2.3 Description and Sample Item for Each Scale in WIHIC

Scale Name	Description	Sample Item
Student Cohesiveness	This scale assesses the extent to which students know, help, and are supportive of one another.	I make friends among students of this class.
Teacher Support	This scale assesses the extent to which the teacher helps, befriends, trusts, and shows interest in students.	The teacher takes a personal interest in me.
Involvement*	This scale examines the extent to which students have attentive interest, participate in discussions, perform additional work, and enjoy the class.	I discuss ideas in class.
Investigation*	This scale assesses the extent to which the skills and processes of inquiry are emphasised and their use in problem solving and investigation.	I carry out investigations to test my ideas.
Task Orientation	This scale assesses the extent to which it is important to complete activities planned and to stay on the subject matter.	Getting a certain amount of work done is important to me.
Cooperation*	This scale assesses the extent to which students cooperate rather than compete with one another on learning tasks.	I cooperate with other students when doing assignment work.
Equity	This scale examines the extent to which students are treated equally by the teacher.	The teacher gives as much attention to my questions as to other students' questions.

Adapted from Aldridge, Fraser & Huang (1999)
* These scales were used in my study.

The results from principal components factor analysis followed by varimax rotation led to the revised 56-item version of the WIHIC (eight items in each of the seven scales) that is now widely used in current studies. Aldridge, Fraser and Huang (1999) found that Australian students consistently perceived their learning environments more favourably than did Taiwanese students. Statistically significant differences ($p<0.05$) were found for the WIHIC scales of Involvement, Investigation, Task Orientation, Cooperation and Equity. However, it is interesting to note that Taiwanese students had more positive attitudes towards science as assessed by the Enjoyment of Science Lessons scale from the TOSRA. In this study, qualitative methods were used in combination with quantitative methods to provide a more indepth understanding to the learning environment. In terms of the qualitative data analysis, it was found through student interviews that students interpreted items in ways that were reasonably consistent with other students within the same country. Interviews also generated plausible explanations for statistically significant differences between the two countries as assessed by the WIHIC.

The WIHIC was comprehensively validated in another separate cross-national study by Dorman (2003) using a sample of 3,980 high school mathematics students from Australia, UK and Canada. Dorman's novel contribution was that he used confirmatory factor analysis within a structural equation modelling framework to confirm the international applicability and validity of the WIHIC. In addition to validating the WIHIC, Dorman demonstrated the invariance of the factor structure of the WIHIC across the three countries, grade levels (Grade 8, 10 and 12) and sexes.

In another study, Dorman (2008) administered both the actual and preferred forms of the WIHIC to a sample of 978 secondary-school students in Australia. Separate confirmatory factor analyses for the actual and preferred forms supported the seven-scale *a priori* structure of the instrument, indicating that the model was a good fit to the data. The use of multi-trait–multi-method modelling, with the seven scales as traits and two forms of the instrument as methods, supported the WIHIC's construct validity. This research further supports and provides strong evidence for the "sound psychometric properties of the WIHIC" (p. 179).

Although the WIHIC is one of the more recent instruments, it has been proven to be a useful tool and it has been used successfully and extensively in its original form or in its modified form. Table 2.4 reports a list of 23 studies which have made use of the WIHIC in various countries (including Asia) and in various languages.

For each of the studies listed in Table 2.4, details include the country, language involved and the size and nature of the sample. In addition, each study listed also reported evidence to support the factorial validity and internal consistency reliability of the WIHIC. Several of the studies also furnished evidence of the ability of the WIHIC to differentiate between the perceptions of students in different classrooms. The second-last column of Table 2.4 identifies for which specific student outcomes the relationships between environment and outcomes were reported for each of the studies where applicable.

The first four studies shown in Table 2.4 are examples of cross-national studies conducted in Australia and Taiwan in two languages by Aldridge and Fraser (2000), in Australia, the UK and Canada in English by Dorman (2003), in Australia and Indonesia in two languages by Fraser, Aldridge and Adolphe (2010) and in Australia and Canada by Zandvliet and Fraser (2005). The next seven studies involved administration of the WIHIC in English in Singapore by Chionh and Fraser (2009), Khoo and Fraser (2008) and Peer and Fraser (in press), in India by Koul and Fisher (2005), in Australia by Dorman (2008), in South Africa by Aldridge, Fraser and Ntuli (2009) and in Canada by Raaflaub and Fraser (2013). The twelfth and thirteenth studies listed used the WIHIC in other languages, namely, in Korean by Kim, Fisher and Fraser (2000) and in Indonesian by Wahyudi and Treagust (2004). The next two studies conducted by MacLeod and Fraser (2010) and Afari and colleagues (2013) in the United Arab Emirates involved the use of an Arabic translation of the WIHIC.

The last eight studies were all undertaken in the USA and they include three studies undertaken in California by den Brok, Fisher, Rickards, and Bull (2006), Martin-Dunlop and Fraser (2008) and Ogbuehi and Fraser (2007); one study in New York by Wolf and Fraser (2008); and four studies in Florida by Pickett and Fraser (2009), Allen and Fraser (2007), Robinson and Fraser (2013) and Helding and Fraser (2013). The four studies in Miami involved the use of an English-language version of the WIHIC, with three of them providing students the option of responding to either a Spanish or an English version of the WIHIC.

The above studies attest the flexibility of the WIHIC for use in various contexts ranging from early primary classrooms (Allen & Fraser, 2007) to professional development programs for those already teaching (Pickett & Fraser, 2009).

Table 2.4 Overview of Studies Involving the Use of the WIHIC

Reference(s)	Country(ies)	Language(s)	Sample(s)	Factorial Validity & Reliability	Associations with Environment for:	Unique Contributions
Aldridge, Fraser & Huang (1999); Aldridge & Fraser (2000)	Australia Taiwan	English Mandarin	1,081 (Australia) and 1,879 (Taiwan) junior high science students in 50 classes	✓	Enjoyment	Mandarin translation Combined quantitative and qualitative methods
Dorman (2003)	Australia UK Canada	English	3,980 high school students	✓	NA	Confirmatory factor analysis substantiated invariant structure across countries, grade-levels & sexes.
Fraser, Aldridge & Adolphe (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	1,404 students in 81 networked classes	✓	Satisfaction	Involved both physical (ergonomic) and psychosocial environments
Chionh & Fraser (2009)	Singapore	English	2,310 grade 10 geography and mathematics students	✓	Achievement Attitude Self-esteem	Differences between geography and mathematics classroom environments were smaller than between actual and preferred environments.
Khoo & Fisher (2008)	Singapore	English	250 working adults attending computer education courses	✓	Satisfaction	Adult population Males perceived more trainer support and involvement but less equity.
Peer & Fraser (in press)	Singapore	English	1,081 primary school students in 55 classes	✓	Two attitude scales (Attitude to Inquiry and Enjoyment)	Differences in learning environment according to sex, grade-level and stream
Koul & Fisher (2005)	India	English	1,021 science students in 31 classes	✓	NA	Differences in classroom environment according to cultural background

Dorman (2008)	Australia	English	978 secondary school students	✓	NA	Multitrait–multimethod modelling validated actual and preferred forms.
Aldridge, Fraser & Ntuli (2009)	South Africa	English	1,077 grade 4–7 students	✓	NA	Pre-service teachers undertaking a distance-education program used environment assessments to improve teaching practices.
Raaflaub & Fraser (2013)	Canada	English	1,173 Grade 7–12 students	✓	Attitudes	Large differences between actual and preferred classroom environments Females perceived the learning environment more favourably but males reported more positive attitudes
Kim, Fisher & Fraser (2000)	Korea	Korean	543 grade 8 science students in 12 schools	✓	Attitudes	Korean translation Sex differences in WIHIC scores
Wahyudi & Treagust (2004)	Indonesia	Indonesian	1,400 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 et al. (2006)	California, USA	English	665 middle-school science students in 11 schools	✓	NA	Girls perceived the environment more favourably.

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 mathe-matics students	✓	Two attitude scales	Used 3 WIHIC and 3 CLES scales Innovative teaching strategies promoted task orientation.
Wolf & Fraser (2008)	New York, USA	English	1,434 middle-school science students in 71 classes	✓	Attitude Achievement	Inquiry-based laboratory activities promoted cohesiveness and were differentially effective for males and females.
Pickett & Fraser (2009)	Florida, USA	English	573 grade 3–5 students	✓	NA	Mentoring program 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 and 5 students	✓	Attitude 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 kinder-garten science students	✓	Achievement Attitude	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 and 10 science classes	✓	Attitude Achievement	Spanish translation Students of NBC teachers had more favourable classroom environment perceptions.

Source: Based on Fraser (2012)

Allen and Fraser (2007) conducted a pioneering study of how parents and students perceive the science learning environment. The WIHIC was modified for young students and parents and was then administered to 520 Grade 4 and 5 students and 120 parents. Data analyses supported the WIHIC's factorial validity, internal consistency reliability and ability to differentiate between the perceptions of students in different classrooms. Both students and parents preferred a more positive classroom environment than the one perceived to be actually present, but effect sizes for actual–preferred differences were larger for parents than for students. Associations were found between some learning environment dimensions (especially Task Orientation) and student outcomes (especially Attitudes). Qualitative methods suggested that students and parents were generally satisfied with the classroom environment, but that students would prefer more Investigation while parents would prefer more Teacher Support.

Pickett and Fraser (2009) made use of the WIHIC to evaluate a two-year mentoring program in science for beginning elementary-school teachers. The sample consisted of seven beginning Grade 3–5 teachers in south-eastern United States and their 573 elementary school students. When a modified version of the WIHIC was used to assess student perceptions of classroom learning environment as a pretest and a posttest, use of MANOVA and effect sizes supported the efficacy of the mentoring program in terms of some improvements over time in the classroom learning environment, as well as in students' attitudes and achievement.

The WIHIC has also been utilised to evaluate the effectiveness of programs. For example, Martin-Dunlop and Fraser (2008) selected learning environment scales from the WIHIC and SLEI to evaluate an innovative science course for prospective elementary teachers in a large urban university in California. When the questionnaire was administered to 525 females in 27 classes, very large differences were found for all scales (of over 1.5 standard deviations) between students' perceptions of the innovative course and their previous courses.

In New York, Wolf and Fraser (2008) evaluated the effectiveness of using inquiry-based laboratory activities in terms of learning environment, attitudes and achievement. Administration of the WIHIC to 1,434 middle-school science students in 71 classes supported its validity and analyses for a subsample of students revealed that inquiry instruction promoted more Student Cohesiveness than non-inquiry instruction (effect size of one-third of a standard deviation).

It is also noteworthy that the WIHIC has been popular in Asian countries. Within Singapore, the WIHIC has proved to be a versatile tool that has been used for different subject and at different grade areas. For example, Chionh and Fraser (2009) cross-validated an English 70-item version of the WIHIC questionnaire with 2,310 Singapore Grade 10 students in 75 randomly-selected geography and mathematics classes from 38 randomly-selected schools. A seven-scale factor structure was strongly supported and the alpha reliability of each scale was high. Differences between the classroom environments of geography and mathematics classes were small relative to the large differences between students' actual and preferred classroom environments.

In another study conducted by Khoo and Fraser (2008) in Singapore, the WIHIC was adapted for use in the evaluation of adult computer application courses. Scales such as Teacher Support were renamed Trainer Support. The sample consisted of 250 working adults attending five computer education centres in Singapore. Various analyses supported the factorial validity and reliability of the WIHIC when used with this adult sample in the Singaporean context. Generally, students perceived their classroom environments positively, with this pattern varying only a little for students of different sexes and ages. However, males perceived significantly more Involvement, whereas females perceived more Equity. Also, whereas males' perceptions of Trainer Support were independent of age, older females had more positive perceptions than younger females.

The WIHIC has been successfully translated into various languages to suit the particular contexts and purposes of the various studies. A cross-validation study by Aldridge, Fraser and Huang (1999) and Aldridge and Fraser (2000), which made use of an English and Mandarin version of the WIHIC, supported the flexibility of this questionnaire when translated into another language. The sample consisted of 1,081 Australian students and 1,879 Taiwanese students in 50 classes who responded to the WIHIC in English and Chinese, respectively. Analyses supported the WIHIC's factorial validity, internal consistency reliability (alpha coefficient), discriminate validity and ability to differentiate between the perceptions of students in different classrooms.

In a study conducted in Korea, a Korean version of WIHIC was validated by Kim, Fisher and Fraser (2000) with 543 Grade 8 science students. Associations between learning environment and attitudes, as well as sex differences in students' perceptions, were explored. Again, the WIHIC was cross-validated and positive relationships were found between the learning environment and attitudes. One unusual finding that arose from this study that was different from other studies was that boys, when compared to girls, perceived their science learning environments more favourably and had more positive attitude towards science.

The pertinence of WIHIC scales in today's setting made it an ideal choice for the present study of science learning environments at the primary-school level in Singapore. Its robust nature across different subjects, countries and languages also made it an appealing choice. In my study, three of the seven scales from the WIHIC which were considered to be relevant were used: Involvement, Investigation and Cooperation. The selection and modifications of the WIHIC scales for use in the present study are described in greater detail in Chapter 3, Section 3.3.1.

2.6 Research in the Field of Learning Environment

The wide range of learning environment questionnaires has been used in different types of research. This section highlights three main types of past research: associations between classroom environment and student outcomes (Section 2.6.1); differences between students' and teachers' perceptions of actual and preferred environment (Section 2.6.2); and investigation of sex differences in learning environment perceptions (Section 2.6.3).

2.6.1 Associations Between Classroom Environment and Student Outcomes

A strong theme in past classroom learning environment research has involved investigations into associations between students' cognitive and affective learning outcomes and their perceptions of psychosocial characteristics of their classroom environments (Fraser & Fisher, 1982a; Haertel, Walberg & Haertel, 1981; McRobbie & Fraser, 1993). Numerous studies have shown that, when classroom environment perceptions have been used as predictor variables, associations between student cognitive and affective outcomes and learning environment have been found.

For example, the WIHIC questionnaire has been utilised in conjunction with the Test of Science-Related Attitudes (TOSRA; Fraser, 1981) in investigating associations between the learning environment and students' affective and cognitive outcomes in numerous studies with large samples of students around the world (Aldridge, Fraser & Huang, 1999; Fraser, Aldridge & Adolphe, 2010; Wolf & Fraser, 2008; Zandvliet & Fraser, 2004, 2005). Table 2.4 shows a tabulation of 23 studies that have involved the validation and use of the WIHIC. This table also shows that 15 of them included investigation of associations between classroom learning environment and various outcomes.

The study of associations between classroom environment dimensions and student outcomes also has been conducted with other learning instruments. For example, den Brok, Fisher and Scott (2005) investigated relationships between students' perceptions of their teachers' interpersonal behaviour and their subject-related attitude in primary science classes in Brunei. Teacher–student interpersonal behaviour was mapped with the Questionnaire on Teacher Interaction (QTI) and reported in terms of two independent dimensions called Influence (teacher dominance vs. submission) and Proximity (teacher cooperation vs. opposition). While prior research using the QTI mainly focused on secondary education, den Brok et al.'s study was one of the first in Brunei and in primary education and one of few studies to use multilevel analysis. Data from 1,305 students from 64 classes revealed strong and positive effects of Influence and Proximity on students' Enjoyment of their Science Class and supported findings of earlier work with the QTI.

Several researchers in Asia have also undertaken various studies of associations between student outcomes and their learning environment. Within Singapore where my study is conducted, Goh and Fraser (1998) sampled 1,512 primary school students and reported relationships between a variety of student outcomes and students' classroom environment perceptions as assessed by the MCI and QTI. Positive associations between student attitudes and learning environment among 1,592 final-year secondary chemistry students from 56 classes in 28 schools in Singapore were reported by Wong and Fraser (1996). Relationships between the chemistry laboratory classroom environment and teacher–student interaction and student attitudes towards chemistry for 200 gifted secondary-school students were reported in Singapore (Quek, Wong & Fraser, 2005). Two questionnaires, the Chemistry Laboratory Environment Inventory (CLEI) and Questionnaire of Chemistry Related Attitudes (QOCRA), were administered in these studies.

My study investigated whether associations existed between students' attitudes and the nature of the learning environment in the context of primary science classrooms.

2.6.2 Differences Between Students' and Teachers' Perceptions of Actual and Preferred Environment

Various educational researchers have used learning environment instruments in investigating differences between students and teachers in their perceptions of the same actual classroom environment and differences between the actual environment and that preferred by students or teachers. In a study by Fisher and Fraser (1983a), the ICEQ was used with a sample of 116 classes for a comparison of student actual with student preferred scores and with a sub-sample of 56 of the teachers of these classes for contrasting teachers' and students' scores. It was reported that students preferred a more positive classroom environment than was actually present for all five ICEQ dimensions. Also, teachers perceived a more positive classroom environment than did their students in the same classrooms on four of the ICEQ's dimensions.

The pattern in which students prefer a more positive classroom learning environment than the one perceived as being currently present has been replicated in several studies in different countries. In Singapore, Chionh and Fraser (2009) administered the WIHIC to 2,310 grade 10 students in 75 geography and mathematics classes in 38 schools and reported that differences between the classroom environments of geography and mathematics classes were small relative to the large differences between students' actual and preferred classroom environments.

Another study conducted by MacLeod and Fraser (2010) involved using the WIHIC with a sample of 763 college students in 82 classes in Dubai. Comparison of students' scores on actual and preferred forms of the questionnaires revealed that students preferred a more positive classroom environment on all scales.

These studies replicate patterns emerging in many other studies in school classrooms in the USA (Moos, 1979), Australia (Fraser & McRobbie, 1995) and The Netherlands (Wubbels, Brekelmans & Hooymayers, 1991). One of the objectives in my study was to investigate differences in students' perceptions of their actual and preferred classrooms. Because no previous study into actual–preferred differences has been undertaken in primary science classrooms in Singapore, my study filled this gap.

2.6.3 Sex Differences in Learning Environment Perceptions

Students' perceptions of the classroom environment have been used as criterion variables in the investigation of differences between perceptions of the classroom environment held by girls and boys. In past studies, significant differences have been found between males and females in terms of students' learning environment perceptions (Fisher, Fraser & Rickards, 1997; Fraser, Giddings & McRobbie, 1995; Khoo & Fraser, 2008)

Fraser, Giddings and McRobbie's (1995) study of Australian senior high school science laboratory classrooms suggested that females generally had more positive perceptions of their classroom learning environments than did males in the same classrooms. Similarly, in a study involving use of the QTI among 497 tenth-grade chemistry students in Singapore, Quek, Wong and Fraser (2005) found that females reported more positive classroom environment perceptions than males in terms of teachers being more helpful/friendly, giving students more responsibility, and being less dissatisfied and strict. However, other past studies reviewed below have revealed that males had more favourable perceptions than females on some learning environment dimensions.

In a study involving 250 working adults undertaking computer application courses in Singapore, females perceived significantly higher levels of classroom equity, whereas males perceived significantly greater class involvement (Khoo & Fraser, 2008). Another study by Hofstein, Cohen and Lazarowitz (1996) compared actual and preferred environments of biology and chemistry laboratories between male and female eleventh-grade students in Israel and reported sex differences in the actual biology learning environment but not in the actual chemistry environment. Girls rated their actual biology classes more favourably than did boys on the scales of Teacher Support, Involvement and Student Cohesiveness, but the opposite was true for Open-Endedness. Greater sex differences were found with the preferred form than with the actual form. For the preferred chemistry environment, mean scores for Open-Endedness were higher for boys than for girls and, for the preferred biology environment, girls' mean scores for seven of the eight scales (except Open-Endedness) were higher.

2.6.4 Combining Quantitative and Qualitative Research Methods

In Taiwan and Australia, Aldridge and Fraser (2000) conducted a cross-national study of classroom environments using mixed methods. The WIHIC, together with a scale from TOSRA to assess students' satisfaction in terms of enjoyment of science lessons, were administered to 1,081 Grade 8 and 9 general science students from 50 classes in 25 schools in Western Australia and 1,879 Grades 7–9 students from 50 classes in 25 schools in Taiwan. It was found that Australian students consistently perceived their environments more favourably than their Taiwanese counterparts. Students in Taiwan, however, reported significantly more positive attitudes towards science than did students in Australia. The researchers also further examined students' perceptions in each country using classroom observations, interviews with teachers and students, and narrative stories and concluded the study with three important points. Firstly, while the classroom environments were found to be different in the two countries, the questionnaire scores did not reflect fully the overall quality of education. Secondly, when interpreting the data for scales of the WIHIC questionnaire, there was a need to consider whether the scales reflected what was considered to be educationally important in the countries and cultures from which the data were collected. Finally, researchers felt that it was necessary to exercise caution in the comparison of quantitative data from different countries because there were some items that students in one country might have interpreted slightly differently from students in another country.

In South Florida, Allen and Fraser (2007) used the WIHIC with Grade 4 and 5 students to investigate parents' and students' perceptions of science classroom learning environments. Associations were found between some learning environment dimensions (especially Task Orientation) and student outcomes (especially Attitudes). Qualitative methods used in this study suggested that students and parents were generally satisfied with the classroom environment, but that students would prefer more investigation while parents would prefer more teacher support.

Another study conducted in Florida involved an evaluation of the effectiveness of the Class Banking System (CBS), an innovative mathematics program, with a sample of Grade 5 students (Spinner & Fraser, 2005). Qualitative data in the form of classroom observations and student interviews were collected to enhance quantitative findings. The qualitative data supported the effectiveness of the CBS in improving elementary mathematics students' attitudes towards mathematics, perceptions of the classroom learning environment, and conceptual development.

In South Africa, Aldridge, Laugksch, Seopa and Fraser (2006) developed and validated a questionnaire that can be used to assess students' perceptions of their learning environment as a means of monitoring and guiding changes towards outcomes-based education. In the first phase, data collected from 2,638 Grade 8 science students from 50 classes in 50 schools in the Limpopo Province of South Africa were analysed to provide evidence about the reliability and validity of the new instrument. In the second phase, two qualitative case studies were used to investigate whether the profiles of class mean scores on the new instrument could provide an accurate and reliable description of the learning environment of individual science classes.

Fraser (2007) also cited a few Asian studies which made use of qualitative methods, such as interviews, to check the suitability of a learning environment instrument so that it could be modified before launching a large-scale study. For example, in Korea, Lee, Fraser and Fisher (2003) conducted classroom observations and interviews with students and teachers. They found that teacher–student interactions in Korean senior high school science classrooms reflect the general image of the youth–elder relationship in society as well as the senior high school's unique nature – portraying a scene of 'directing teachers and obeying students'.

2.7 Students' Attitudes Towards Science

In recent educational research, much attention has been focused on affective outcomes, particularly attitudes, because they are as important as cognitive variables in influencing learning and other outcomes (Koballa, 1988). In my study, in addition to assessing primary school students' perceptions of the learning environment, objectives included investigating determinants of students' attitudes as well as associations between classroom environment and students' attitudes. This section is devoted to reviewing literature related to the assessment of students' attitudes.

Although the promotion of favourable science-related attitudes is considered in many countries to be one of the most important aims of science education, throughout the past two decades, science educators have been struggling with defining science attitudes (Shrigley, Koballa & Simpson, 1988) and differentiating among attitudes, beliefs and values (Koballa, 1988). Many characteristics were used to describe attitudes, such as interest, enjoyment and satisfaction (Gardner & Gauld, 1990) and even curiosity, confidence and perseverance (Shulman & Tamir, 1972). It was generally agreed that attitude is not innate, but learned as part of culture (Shrigley, 1983).

The varied interpretations of the term 'attitudes towards science', as well as the semantic problems associated with it, were perceived as a common problem among science teachers. This problem was alleviated by Klopfer (1971) when he provided a comprehensive classification scheme for science education aims and narrowed the multiple meanings attached to the term attitude to science to six different categories of mental disposition. These categories are: manifestation of favourable attitudes to science and scientists; acceptance of scientific enquiry as a way of thought; adoption of scientific attitudes, enjoyment of science learning experiences; development of interest in science and science-related activities; and development of interest in pursuing a career in science. The Test of Science-Related Attitudes (TOSRA), designed to measure these categories separately, was subsequently developed for use with secondary school students (Fraser, 1978, 1981).

Two scales, namely, Attitude to Inquiry and Enjoyment of Science Lessons from the widely-used Test of Science-Related Attitudes (TOSRA, Fraser 1981) were selected for use in this study. The following subsections describe the TOSRA, including its conceptualisation and validation, and provide a review of studies that have made use of the instrument in investigating associations between the classroom learning environment and attitudes.

2.7.1 Development, Validation and Use of the Test of Science-Related Attitudes (TOSRA)

Fraser's original TOSRA consisted of five scales: Social Implications of Science, Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons and Leisure Interest in Science. This original version of the TOSRA was field-tested and validated with a large sample of 1,323 Year 7 students in Melbourne, Australia and it was shown to have satisfactorily high reliability (Fraser, 1977a, 1977b). These scales were then extended to include two new scales, Normality of Scientists and Career Interest in Science, with each of the seven scales containing the same number of items (namely, 10) to facilitate ready comparison between scores on different scales. Another improvement was having a single set of instructions and answering format. Students express their degree of agreement with each statement in TOSRA on a five-point scale described by Likert (1932), which consist of the responses Strongly Agree (SA), Agree (A), Not sure (N), Disagree (D), and Strongly Disagree (SD). This new version of TOSRA was validated with a large sample of 1,337 junior high school students in Sydney at all four junior high school grade levels (Years 7–10) in 1977.

Results revealed that the seven TOSRA scales exhibited good internal consistency reliability at each of the grade levels, with an average Cronbach alpha coefficient of 0.80 for all scales. Inter-correlations among TOSRA scales were calculated as indices of discriminant validity (the extent to which a given scale measures a unique attitude not measured by other scales in the battery). It was found that the TOSRA scale inter-correlations were generally low with a mean of 0.33 (Fraser, 1981). Since its initial validation in 1977, the TOSRA has been administered to new samples of secondary science students in Australia and the United States to obtain cross-validation data. An Australian sample totalled 2,593 junior and senior-high school students while a sample from Philadelphia consisted of 546 ninth-grade students. Fraser (1981) reported that all cross-validation data were favourable and that not only would the data provide additional support for the validity of TOSRA for use with Australian students, but they also supported the cross-cultural validity of TOSRA for use in the United States. Table 2.5 shows the name of the seven scales contained in TOSRA, together with the classification of the aim measured by each scale according to Klopfer's (1971) scheme.

Since the inception of the TOSRA, numerous studies using the original or modified versions have been undertaken in several countries. A reason for its widespread use is that the TOSRA has the major advantage over some other science attitude instruments that it yields a separate score for a number of distinct attitudinal aims instead of a single overall score, making it possible to obtain a profile of attitude scores for groups of students. The following section reviews several studies undertaken previously in which the TOSRA was used to investigate associations between the classroom learning environment and attitudes.

Table 2.5 Name and Classification of Each Scale in Test of Science-Related Attitudes (TOSRA)

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

Source: Fraser (1981)
Items designated (+) are scored 1, 2, 3, 4, 5 respectively, for the responses Strongly Disagree, Disagree, Not Sure, Agree and Strongly Agree. Items designated (-) are scored in the reverse manner. Missing or invalid responses are scored 3.
* Modified versions of these scales were used in my study.

2.7.2 Associations Between the Classroom Learning Environment and Attitudes Towards Science

The TOSRA has been used frequently in learning environments research for investigating associations between classroom learning environment and the student outcome of attitudes. Researchers have used anywhere from one scale to all seven scales from the TOSRA in their studies.

In one of the earlier studies involving the use of TOSRA, Fraser and Butts (1982) explored relationships between perceived levels of classroom individualisation and science-related attitudes for a sample of 712 junior high school science students. Five dimensions of perceived individualisation (Personalisation, Participation, Independence, Investigation, and Differentiation) were measured with the ICEQ, while seven distinct attitudes were measured with the TOSRA. Hierarchical regression analyses revealed that student perceptions on the set of individualisation variables accounted for a significant increment in end-of-year attitude scores, beyond that attributable to corresponding beginning-of-year attitude scores, for four of the seven attitudes considered (Social Implications of Science, Enjoyment of Science Lessons, Leisure Interest in Science, and Career Interest in Science). Significant associations between an individual individualisation variable and an attitudinal dimension were positive in all cases. The study also provided support for the reliability and validity of the ICEQ and TOSRA and for their general usefulness in science education research.

The TOSRA has been well used in both the Western and the non-Western countries. In the USA, Bull (2001) made use of a questionnaire that included the WIHIC and an attitude to class scale from TOSRA in examining associations of students' perceptions of the classroom environment with sex, racial diversity, socio-economic status and ethnicity. The sample from eighth-grade classrooms consisted of 1,720 students in 65 classes in 11 schools from one USA state, namely, California. The research combined quantitative and qualitative methods, with the qualitative portion of the study involving 74 interviews. This study is distinctive in that it provided a large database of student perceptions of science classroom environments and allowed new insights into associations between student perceptions and sex, racial diversity, socio-economic status and ethnicity. Student attitudes were found to be positively associated with students' perceptions of their classroom environment.

Also, within the USA in a large urban university in Southern California, Martin-Dunlop and Fraser (2008) evaluated the impact of a science course for prospective elementary teachers on their perceptions of the learning environment, attitudes towards science, and understandings of the nature of science. The sample consisted of 525 female students enrolled in 27 classes of A Process Approach to Science (SCED 401). Using both qualitative and quantitative methods, perceptions of the learning environment were measured using scales from the SLEI (Open-Endedness and Material Environment) and the WIHIC (Student Cohesiveness, Instructor Support, Cooperation, Investigation), whereas attitudes towards science were assessed using the Enjoyment of Science Lessons scale from the TOSRA. This study replicated past research in that statistically significant positive correlations existed between all six learning environment scales and Enjoyment of Science Lessons. However, Instructor Support had the largest independent association with Enjoyment, using both the individual and class mean as the units of analysis (Martin-Dunlop & Fraser, 2008). This research makes a distinctive contribution to the learning environments field because it was the first study to investigate laboratory classroom environments at the university level with prospective elementary teachers. The study has implications for undergraduate laboratory course instructors, for science teacher educators who develop and teach elementary teacher preparation programs, and for future elementary teachers and the science learning of their future students.

In Singapore, Wong and Fraser (1996) modified the TOSRA for use with chemistry students to study the determinants and effects of chemistry laboratory classroom environments. This study was distinctive in that it marked the beginning of science classroom and science laboratory classroom environment research in Singapore and it was the first classroom environment study that used 'stream' as a determinant of classroom environment dimensions. It was also the first time that multilevel analysis was used as a method of data analysis to study the effects of classroom environment dimensions. The sample consisted of 1,592 final-year secondary school (i.e., Grade 10) students studying chemistry and their chemistry teachers in 56 classes from 28 randomly-selected co-educational government schools of similar standard in Singapore. One of the aims of the study was to investigate associations between students' perceptions of chemistry laboratory environments, as assessed by the SLEI, and attitudes towards chemistry. Three of the seven TOSRA scales were renamed slightly for the context of chemistry laboratory environments (Attitude to Scientific Inquiry in Chemistry, Adoption of Scientific Attitudes in Chemistry and Enjoyment of Chemistry Lessons). Besides the use of simple correlational, multiple regression and canonical correlation analyses, multilevel analysis was also used to provide a more accurate picture of environment–attitude links. These analyses showed that there were positive associations between the nature of the chemistry laboratory classroom environment and the students' attitudinal outcomes.

In another study in Korea, Fraser and Lee (2009) employed the use of four questionnaires (three classroom learning environment instruments and one attitude instrument) namely, the CLES, SLEI, QTI and the TOSRA, to investigate the association between students' attitude towards science and their perceptions of their classroom environments. Students from three academic streams were involved in the study, with 99 students from the science-independent stream, 195 students from the science-oriented stream and 145 students from the humanities stream. The following associations between students' attitudes and their learning environments were found. First, students' attitudes to science (represented by Interest in Science) were more likely to be positive in classes where students perceived greater emphasis on notions of constructivism (Personal Relevance, Uncertainty, Critical Voice, Shared Control and Student Negotiation). Second, students' attitudes to science (represented by Social Implications of Science) were more likely to be positive in laboratory classes where students perceived their laboratory lessons more favourably (Student Cohesiveness, Open-Endedness, Integration, Rule Clarity and Material Environment). In particular, the Integration scale (i.e., integration between theory and laboratory classes) accounted for unique variance in all attitudinal scales. Third, students' attitudes to science (represented by Interest in Science) were more likely to be positive in classes where students more frequently perceived teachers' cooperative behaviour (Leadership, Helpful/Friendly, Understanding and Student Responsibility/Freedom behaviours) and less frequently perceived teachers' opposition behaviour (Dissatisfied, Admonishing and Strict, but not Uncertain behaviours). From the commonality analyses, it was revealed that, for most attitudinal outcomes, each classroom environment questionnaire in the three pairs made a unique contribution to attitude variance that was independent of the variance associated with the other questionnaire.

The TOSRA has also been translated and used in cross-national studies. Fraser, Aldridge and Adolphe (2010) validated a modified version of the WIHIC questionnaire and the TOSRA in a cross-national study in Australia and Indonesia. The researchers also aimed to find out whether scores on the WIHIC questionnaire and TOSRA varied with country and with sex, as well as to evaluate the strength of the associations between students' perceptions of their classroom environment and their attitudes to science in both Australia and Indonesia. The sample consisted of 1,161 students (594 students from 18 classes in Indonesia and 567 students from 18 classes in Australia). Once again, the results attested the internal consistency reliability and empirical independence of the TOSRA scales for both the Indonesian and Australian versions. Principal components factor analysis with varimax rotation supported the validity of a revised structure for the WIHIC. The use of two-way MANOVA also revealed that there were a few differences between Australian and Indonesian students' perceptions of their classroom environments and in their attitudes to science. For example, Australian students had more positive attitudes towards Scientific Inquiry while Indonesian students had more positive attitudes towards Career Interest in Science. A comparison between male and female students in the two countries revealed that both genders had almost similar perceptions of their learning environments and attitudes to science. However, female students had slightly higher scores when it came to Career Interest in Science, Student Cohesiveness and Equity. A series of simple correlation and multiple regression analyses revealed reasonably strong and positive associations between each classroom environment scale and the attitude scales. Overall, Teacher Support and Involvement were the strongest independent predictors of student attitudes to science in both Indonesia and Australia.

The TOSRA is versatile and it has been modified and used for other subjects. For example, Walker (2006) developed and validated the Test of Geography-Related Attitudes (ToGRA), an instrument modelled after the TOSRA, and used it with 388 grade nine students from 17 geography classes in San Antonio. This study led to the first validated affective-trait measurement instrument available to secondary-level researchers and practitioners.

In another study by Ogbuehi and Fraser (2007), the TOSRA was modified and renamed as the Test of Mathematics-Related Attitudes (TOMRA) to suit mathematics classes. The study was conducted with 661 middle-school students in 22 classrooms in California to investigate the effectiveness of using innovative teaching strategies for enhancing the classroom environment, students’ attitudes and conceptual development. It was reported that associations existed between perceptions of classroom learning environment and students’ attitudes to mathematics and conceptual development.

In previous studies, the TOSRA has proved to be a valid and reliable instrument for assessing students' attitudes to their classrooms. It has been shown that the questionnaire can be used with students in a wide variety of settings.

2.8 Summary

The major aim of this chapter was to review literature which is relevant to my study and could guide my research. The first section considered literature relevant to the historical background to the field of learning environments, which includes the conceptual contributions made to the field by the important work of Murray (1938) and Lewin (1936). The work of Walberg, who developed the Learning Environment Inventory (LEI) for research on Harvard Project Physics (Walberg & Anderson, 1968), as well as Moos's (1974) creation of the Classroom Environment Scale (CES), are also discussed.

This chapter also provided extensive coverage of the emergence and use of nine widely-recognised classroom environment instruments developed since learning environment research began in the late 1960s, namely, the Learning Environment Inventory (LEI), Classroom Environment Scale (CES), Individualised Classroom Environment Questionnaire (ICEQ), My Class Inventory (MCI), College and University Classroom Environment Inventory (CUCEI), Questionnaire on Teacher Interaction (QTI) and the Science Laboratory Environment Inventory (SLEI). A detailed description of the development, structure and past use of the Constructivist Learning Environment Survey (CLES) and What is Happening In this Class? (WIHIC) were also provided because they were used as a source of scales in my study. Information about their validity and reliability in prior studies was also included.

A section of this chapter also reviewed the different lines of past research that have been pursued in the field of learning environment, especially associations between classroom environment and student outcomes, differences between students' and teachers' perceptions of actual and preferred environment, and sex differences in learning environment perceptions. Instruments used in these studies were highlighted because they provided the basis for the development of the instrument used in my study.

One of my research questions involved investigation of associations between student perceptions of their learning environment and their attitudes. Therefore, a section on student attitudes and a detailed description of TOSRA, an instrument that has been developed to measure attitudes, was included. Developed by Fraser (1981), TOSRA measures seven distinct science-related attitudes among secondary school students. Several past studies using TOSRA with learners at all education levels and from a variety of population groups have established that it has satisfactory validity and reliability.

The final section summarised and concluded this chapter. Based on this, the next chapter provides information about the design of the study, the sample, the instruments used to gather the data and the methods used to analyse the data.

Chapter 3

RESEARCH METHODS

3.1 Introduction

The purpose of this study was to examine the learning environment in primary science classrooms in Singapore. To answer the research questions outlined in Chapter 1, data were collected from a sample of 485 students using the Science Learning Environment and Attitude Questionnaire (SLEAQ). The research questions focussed on:

- the validity and reliability of a science learning environment and attitude questionnaire for use by primary science students in Singapore
- differences between students' perceptions of their actual and preferred learning environments
- sex difference in learning environment and attitudes to science
- relationships between the learning environment and students' attitudes.

This chapter describes the methods that I used within the study. The following headings provide an overview of the chapter:

- Research Approach (Section 3.2)
- Instrument Selection and Modification and Pilot Study (Section 3.3)
  - Modified Science Learning Environment Questionnaire (Section 3.3.1)
  - Test of Science-Related Attitudes (TOSRA) (Section 3.3.2)
  - Scoring for SLEAQ (Section 3.3.3)
  - Actual and Preferred Forms of SLEAQ (Section 3.3.4)
  - Pilot Study Involving SLEAQ (Section 3.3.5)
- Sample for the Main Study (Section 3.4)
- Data Collection for the Main Study (Section 3.5)
- Data Analysis (Section 3.6)
  - Validity and Reliability of the Learning Environment and Attitude Scales of the SLEAQ (Section 3.6.1)

  - Differences Between Students' Perceptions of Actual and Preferred Learning Environment (Section 3.6.2)
  - Sex Differences in Learning Environment Perceptions and Attitudes (Section 3.6.3)
  - Associations Between Students' Attitudes and the Nature of Classroom Learning Environment (Section 3.6.4)
- Summary (Section 3.7).

3.2 Research Approach

In past research, there have been three common approaches for assessing and studying classroom environment. The first of these involves application of techniques of naturalistic and inquiry and case study, the second approach is commonly referred to as interaction analysis and involves systematic observation and coding of classroom communication, and the last approach to studying classroom environment focuses on student and teacher perceptions of psychosocial characteristics of the classroom. It was this third approach that was used in my study. Fraser (1991) outlined five major strengths of this approach: 1) paper-and-pencil measures are more economical than classroom observation techniques that involve the expense of trained outside observers, 2) perceptual measures are based on students' experiences over many lessons, while interaction data are usually restricted to a very small number of lessons; 3) perceptual measures involve the pooled judgements of all students in a class, whereas observation techniques typically involve only a single observer; 4) as students' perceptions are the determinants of student behaviour more so than the real situation, these can be more important than observed behaviours; and 5) perceptual measures of classroom environment typically have been found to account for considerably more variance in student learning outcomes than do directly-observed variables.

3.3 Instrument Selection and Modification and Pilot Study

This section discusses the selection, modification and development of the instruments that were used in the study. The final form of the Science Learning Environment and Attitude Questionnaire (SLEAQ) is made up of two parts, with one section consisting of items which assess the science learning environment and the other section being made up of items which assess the attitudinal outcomes. That is, although the constructs of classroom learning environment (see literature review in Section 2.2–2.6) and student attitudes to science (see literature review in section 2.7) are conceptually distinct and served different purposes in my study, nevertheless, scales measuring these distinct constructs were incorporated into the same instrument (the SLEAQ) for convenience. Having a single questionnaire with one set of instructions and a common response format reduced administration time and potential confusion among students.

The section of the questionnaire assessing the science learning environment questionnaire was formed with scales extracted from the What Is Happening In this Class? (WIHIC) questionnaire (Fraser, Fisher & McRobbie, 1996) and the Constructivist Learning Environment Survey (CLES) (Taylor, Fraser & Fisher, 1997). An additional scale of Connection, developed for this study, was also included. To assess attitudes towards science, I used two scales, Attitude to Scientific Inquiry and Enjoyment of Science Lessons, from the Test of Science-Related Attitudes (TOSRA) (Fraser, 1981).

The SLEAQ consists of 50 items spread over a four-page form. On the first page, students were asked to indicate their school, name and index number, as well as their sex. The questionnaire was administered to all graduating students during the last term of their academic year in primary school during a 30-minute timeslot allocated for this. All information was entered into an Excel spread sheet which was then exported into the Statistical Package for Social Sciences (SPSS), a data-analysis software application with which further analysis was undertaken.

3.3.1 Modified Science Learning Environment Questionnaire

The thrust of science education in Singapore as indicated in the Primary Science Syllabus (2008) (CPDD, 2007) is to prepare students to be sufficiently adept as effective citizens to be able to function in and contribute to an increasingly technologically-driven world. The syllabus emphasises the teaching of science as inquiry and encourages teaching and learning approaches that nurture students as inquirers. Teachers are facilitators and role models of inquiry and they are expected to be able to take advantage of various strategies for incorporating the essential features of inquiry, which include questioning, collecting evidence, explaining the evidence, connecting with other sources of knowledge and communicating explanations in a logical way in order to engage students in the learning of science (CPDD, 2007).

A major contribution of this study was to develop and validate a learning environment questionnaire for use by primary science students who were experiencing science being taught as inquiry.

Table 3.1 Overview of WIHIC and CLES Scales Used to Assess Science Learning Environment

	Scales Classified According to Moos's Scheme		
Instrument	Relationship	Personal development	System maintenance and change
WIHIC	Involvement (8)*	Investigation (8) Cooperation (8)	
CLES			Student Negotiation (6)

*Numbers in parentheses indicate number of items in that scale.

From the extensive list of existing classroom learning environment instruments, relevant scales that aligned with the essential features of inquiry were selected to form the items in the learning environment part of the SLEAQ. Three scales (Involvement, Investigation and Cooperation) from the WIHIC were included. The scales of Involvement and Investigation have items that align with the essential features of inquiry. Items found in the scale of Involvement were able to assess the extent to which students engage in asking questions and the items in the scale of Investigation were able to assess the extent to which students were involved in investigating to find evidence for their questions. Although the scale of Cooperation did not have items which aligned with any of the essential features of inquiry, it was included as it contained items which were able to assess the extent to which students cooperate rather than compete with one another on learning tasks, a skill which is important in order for inquiry to take place effectively in the classroom.

Besides having scales that were aligned with the essential features of inquiry, the WIHIC was also chosen for three other reasons. First, it is the most widely-used instrument, second, it does not contain any reverse-scored items and, third, it "combines scales from several past questionnaires to bring parsimony to the field of learning environments" (Aldridge, Fraser & Huang, 1999, p. 49). The robust nature of the WIHIC has allowed it be widely used across different subjects, countries and languages, with many of these studies reporting evidence to support the factorial validity and internal consistency reliability of the questionnaire (Aldridge & Fraser, 2000; Aldridge, Fraser & Huang, 1999; Chionh & Fraser, 2009; Kim, Fisher & Fraser, 2000; MacLeod & Fraser, 2010; Wahyudi & Treagust, 2004).

The scale of Student Negotiation from the Constructivist Learning Environment Survey (CLES) was also included among the learning environment scales of the SLEAQ as it contains items which are able to assess the extent to which students explain and communicate their ideas to their teacher and friends. Although the main reason for the selection of this scale for inclusion in the SLEAQ was that it aligned with the essential features of inquiry, the CLES was also chosen as it had been proven to be reliable and valid in a variety of classroom environments around the world. Consistent validity support has been found in numerous studies with the CLES conducted in elementary, middle and high schools in various countries, including Australia and Taiwan (Aldridge, Fraser, Taylor & Chen, 2000), Korea (Kim, Fisher & Fraser, 1999), the United States (Nix, Fraser & Ledbetter, 2005) and South Africa (Aldridge, Fraser & Sebela, 2004).

The last scale in the learning environment survey of the SLEAQ, Connection, which consists of 8 items, was developed for this study to assess the extent to which students are able to make connections between what they have learned in science and their daily experiences. Connection captures how students perceive what they have learned and are able to use the scientific knowledge to identify questions, and to draw evidence-based conclusions in order to understand and make decisions about the natural world and the changes made to it through human activity. Some of the items in this scale are "I can apply science to my everyday life" and "I can make connections between my findings and scientific knowledge"

Table 3.2 **Description and Origin of Each Science Learning Environment Scale and its Relevance to the Teaching and Learning of Science as Inquiry**

Scale	Origin of scale	Description of scale	Sample items	Relevance to teaching of science as inquiry
Involvement	WIHIC	Students participate in class through discussions. They do work and enjoy the class.	I discuss ideas in class. I ask my teacher questions.	Learners are engaged in asking questions to find out the things around them.
Investigation	WIHIC	Students make use of their problem-solving and investigation skills to find the answers to their questions.	I carry out investigations to answer questions coming from discussions. I solve problems by using information obtained from my own investigations.	Learners are involved both hands-on and minds-on as they collect evidence to answer their questions.
Cooperation	WIHIC	Students cooperate with their friends on activities.	I cooperate with other students on class activities. I learn from other students in this class.	Learners collaborate and cooperate with each other in the learning process.
Student Negotiation	CLES	Students communicate by explaining their ideas and learning to their friends.	I explain my understanding to other students. Other students explain their ideas to me.	Learners justify their explanations and communicate their ideas to their friends.
Connection	Developed for this study	Students relate and apply what they have learnt to their daily experiences around them.	I learn how science can be part of my life. My teacher helps me to apply what I learn to the world around me.	Learning is authentic and meaningful to learners. Learners would be able to make connections between what they have learnt and their daily experiences.

A total of 38 items comprised the science learning environment questionnaire, with all three of Moos's dimensions being represented. Table 3.1 shows the name of each learning environment scale in the SLEAQ and the classification of each scale according to Moos's (1974) scheme for classifying human environments: (1) Relationship dimensions, which focus on the interpersonal relationships between students and between students and the teacher in a classroom; (2) Personal Development dimensions which assess basic directions along which personal growth and self enhancement tend to occur; and (3) System Maintenance and Change dimensions which include attributes such as classroom control and order as well as responsiveness to change.

Table 3.2 shows the name and description of each scale in the learning environment part of the in SLEAQ, its origin and sample items. It also shows how each of the scale is aligned to the teaching of science as inquiry.

3.3.2 Test of Science-Related Attitudes (TOSRA)

To assess students' attitudes towards science, the Test of Science-Related Attitudes (TOSRA) was used. Fraser (1978) developed the TOSRA to measure seven distinct science-related attitudes among secondary school students: Social Implications of Science, Normality of Scientists, Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science, and Career Interest in Science. Each scale contains 10 items, making a total of 70 items for the whole instrument.

The TOSRA is actually an extension and improvement of a previous set of five attitude scales which contained earlier versions of the following five scales: Social Implications of Science, Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, and Leisure Interest in Science (Fraser, 1981). Since its development, the TOSRA has been further cross-validated with several new samples of secondary science classes from Australia, Indonesia and Singapore:

- 1,041 Year 8–10 students from 11 schools in Perth, Australia (Schibeci & McGaw, 1981)
- 712 Year 7–9 students from 8 schools in Sydney, Australia (Fraser & Butts, 1982);
- 1,594 upper secondary school students from 52 schools in Queensland, Australia (McRobbie & Fraser, 1993).
- 1,592 final-year secondary school students from 28 schools in Singapore (Wong & Fraser, 1996)

- 1,161 Year 9–10 students (594 students from 18 classes in Indonesia and 567 students from 18 classes in Australia) from 8 randomly-selected private coeducational schools (Fraser, Aldridge & Adolphe, 2010)

On the whole, it was found that all cross-validation data compared favourably with the original validation data.

The TOSRA has been found to be a useful and easy-to-use instrument for measuring and monitoring the development of science-related attitudes of individual students or whole classes of students with teachers and researchers (e.g. Fraser, Aldridge & Adolphe, 2010; Fraser & Fisher, 1982a; Lightburn & Fraser, 2007; Wong & Fraser, 1996). Also the TOSRA has been modified for use in other subjects, including geography (Walker, 2006), mathematics (Ogbuehi & Fraser, 2007), Spanish (Adamski, Fraser & Peiro, 2013) and English (Liu & Fraser, 2013). Because past research has confirmed the TOSRA's validity and reliability in various contexts, and also because one of my research questions focused on associations between the learning environment and students' outcomes, the two scales of Attitude to Scientific Inquiry and Enjoyment of Science Lessons from TOSRA were included at the end of the SLEAQ.

For the two attitude scales included in the SLEAQ, all the positively-worded items in these scales were selected. In addition, one of the negatively-worded items was chosen from each of the two scales and rewritten as a positively-worded item, so as to minimise the probability of misinterpretation. Cheung (2009) states: "A combination of positively and negatively worded items was often used by researchers to construct Likert-type scales to reduce the effects of acquiescence and other response biases. However, the 'conventional wisdom' these days is not to mix positive and negative items for a dimension" (p. 79).

Table 3.3 shows the original and modified items from the scales of Attitude to Scientific Inquiry and Enjoyment of Science Lessons of the TOSRA used in my study.

Table 3.3 Wording of Items in Original and Modified Versions of TOSRA

Scale	Original version		Modified version	
	Polarity	Item	Polarity	Item
Attitude to Scientific Inquiry	-	I would rather agree with other people than do an experiment to find out for myself.	+	I would rather do an experiment to find out for myself than to agree with other people.
Enjoyment of Science Lessons	-	I would enjoy school more if there were no science lessons.	+	I would enjoy school more if there were more science lessons.

Source: Fraser (1981)
Items designated (+) in the original scale are scored 1, 2, 3, 4, 5, respectively, for the responses Strongly Disagree, Disagree, Not Sure, Agree and Strongly Agree. Items designated (-) are scored in the reverse manner. Missing or invalid responses are scored 3. In the modified version, items are also scored 1, 2, 3, 4, 5. However the responses were modified: Almost Never, Seldom, Sometimes, Often, Almost Always.

Another modification made was to the response format of TOSRA items. In Fraser's original version of the TOSRA, the response scale is a five-point Likert scale with response categories ranging from Strongly Agree to Strongly Disagree. These were changed to Almost Never, Seldom, Sometimes, Often and Almost Always to provide the same frequency response format for both instruments in order to facilitate administration. This single response format not only saved time, but it also avoided confusion because students were only given one, rather than two, sets of instructions for completing the SLEAQ.

Table 3.4 shows the name and description of each scale in the TOSRA scale included in the SLEAQ together with sample items. It also shows how each scale is aligned with the teaching of science as inquiry.

3.3.3 Scoring for SLEAQ

The 50 items in the SLEAQ are allocated scores of 1, 2, 3, 4 and 5 for the frequency responses of Almost Never, Seldom, Sometimes, Often and Almost Always, respectively. Students simply circle the appropriate number directly on the form. In cases for which students miss entire scales or entire pages, the questionnaires from these students were not be used in the study.

Table 3.4 Description and Origin of Each Attitudinal Scale Included in SLEAQ and its Relevance to the Teaching and Learning of Science as Inquiry

Scale	Origin of scale	Description of scale	Sample items	Relevance to teaching of science as inquiry
Attitude to Scientific Inquiry	TOSRA	Students value experimentation and inquiry as ways of obtaining information about the natural world.	I would prefer to do experiments than to read about them. I would rather solve a problem by doing an experiment than be told the answer.	Acceptance of scientific inquiry as a way of thought.
Enjoyment of Science Lessons	TOSRA	Students are interested in science from the learning experiences which they go through.	Science lessons are fun. I look forward to science lessons.	Enjoyment of science learning experiences.

3.3.4 Actual and Preferred Forms of SLEAQ

Both the WIHIC and CLES are available in both actual and preferred forms. The actual form assesses students' perceptions of how they actually perceive the actual science classroom, whereas the preferred form measures perceptions of the environment ideally liked or preferred. In many studies, the actual and preferred forms are combined into one questionnaire, and they are used for person–environment fit studies of whether students achieve better in their preferred environment. In my study, because one of my research questions involved differences between students' perceptions of their actual and preferred learning environments, both actual and preferred versions of the SLEAQ were created and used.

The response scales for actual and the preferred versions of the SLEAQ items were placed side-by-side on a single form of the questionnaire to provide a more economical format (Aldridge & Fraser, 2008). Using this format, students were required to record what they perceived as actually happening in their class in the actual column and to record what they would prefer to happen in their class in the preferred column.

Figure 3.1 shows sample items from the SLEAQ and illustrates the side-by-side response format for the actual and the preferred forms.

		ACTUAL CLASSROOM (What this class is actually like)					PREFERRED CLASSROOM (What you would prefer this classroom to be like)				
Involvement		Almost Never	Seldom	Some-times	Often	Almost Always	Almost Never	Seldom	Some-times	Often	Almost Always
1	I discuss ideas in class.	1	2	3	4	5	1	2	3	4	5
2	I give my opinions during class discussions.	1	2	3	4	5	1	2	3	4	5

Figure 3.1 Sample Items from the SLEAQ Illustrating the Side-by-Side Response Format for the Actual and the Preferred Forms

3.3.5 Pilot Study Involving SLEAQ

A pilot study was conducted to:

- make sure that the SLEAQ was relevant and comprehensive for the primary level in Singapore;
- check that students' understandings of individual items were consistent with the researcher's understanding;
- provide a guide regarding the amount of time required to administer the questionnaire.

The SLEAQ was pilot-tested with 40 primary 5 students. The pilot study was conducted with primary 5 instead of primary 6 students because the timing when it was conducted coincided with the time when the graduating students were sitting for their national exams and I did not want to disrupt them during this crucial period. However, the ages of the students who took part in the pilot study were close to those of the students who would be taking part in the actual study and their responses would be a good indication to me about whether primary 6 students would comprehend the questionnaire. Each student was asked to complete both the actual and the preferred forms of the questionnaire. The process also involved observation of the class and interviews with the students. Observations of the class took place during the pilot study so as to provide an indication of the kind of practices that were taking place in the classroom. During the study, it appeared that completing both the actual and preferred forms of the SLEAQ took students around 30 minutes to complete.

The intention of the interview process based on the questionnaires responses was to obtain first-hand feedback from students about the readability, comprehensibility and suitability of the questionnaire. On the basis of these interview results, fine-tuning to the wording of individual items was undertaken. Where discrepancies were found, interviews with students were held to ascertain why. The interviews revealed that students' understanding of the items were consistent with those of the researcher.

Appendix A contains the SLEAQ and shows the response alternatives for each item in the final actual and preferred versions of the questionnaire used in the present study.

3.4 Sample for the Main Study

The present study was largely quantitative in nature and involved using questionnaire surveys as the main form of data collection. The sample was drawn from 16 classes across 4 different co-educational schools in Singapore, with each class having about 40 students. On the whole, these students were aged between 11 and 12 years. This target group was chosen because it comprises graduating students who have substantial experience in their science lessons and could 'better inform' about the type of learning experiences which they had experienced. Although the selection of classes was made on the bases of the availability and willingness of the principals who had expressed interest in taking part in the study, there is no reason to suspect that the sample was unrepresentative of the population of students. All in all, 640 students took part in the survey. However, faulty responses surfaced. These included multiple responses, skipped entries, or incomplete returns from parents about allowing their child to take part in the study. These responses were discarded, resulting in the sample size going down to 485 participants.

3.5 Data Collection for the Main Study

Data for the main study were collected using the Science Learning Environment and Attitude Questionnaire (SLEAQ) to assess students' perception of their learning environment as well as their attitudes towards the learning of science. The SLEAQ consisted of scales from well-validated questionnaires including the WIHIC, CLES and the TOSRA.

Organisation of the administration of the questionnaires to the 485 students in the main study was guided by insights from the pilot test, which indicated that questionnaires took an average of 30 minutes for the students to complete. To maximise the quality of the data-collection process, the questionnaires were administered personally by the researcher.

Prior to the administration of the questionnaires, clearance to conduct the study was first sought from Curtin University's Human Research Ethics Committee as it involved humans. Upon approval from the committee, permission was next sought from school principals for their teachers' involvement; following which the permission of teachers for their involvement in the study was sought. At this point, the researcher provided a brief explanation of the aims and expected outcomes of the research and appropriate information was given to teachers to inform them that their involvement was totally voluntary, that they had the option of not participating in the study, and that they could withdraw from the study at any time. They were assured that the results of the study would not be used as a form of evaluation of them as teachers. In addition, the names of the teachers and the schools would not be revealed in any part of the study.

Consent was then also obtained from parents to allow students from the classes involved in the study to complete the questionnaire. Finally, the consent of the participating students was also sought. Similarly, the students were also told that completion of the questionnaire was entirely voluntary, that they would not be disadvantaged in any way should they choose not to respond, and that they could withdraw from the study at any time. They were informed of the confidentiality involved in the study and they were assured that their names would not be identified in the published data. Appendix B provides the consent forms which were given out to the various parties seeking their permission to be involved in the study.

Prior to the administration of the questionnaires, additional instructions related to how students should complete both the actual and preferred forms of the SLEAQ were also given. The entire process took around 40 minutes, after which teachers were able to resume their normal activities.

At the end of the study, 485 questionnaire responses with completed data were identified. Feedback based on the actual and preferred responses from these students were shared with the principals and the teachers who had played a part in the study.

3.6 Data Analysis

This section describes the analysis of the data collected during the present study to answer the research questions outlined in Chapter 1.

3.6.1 Validity and Reliability of the Learning Environment and Attitude Scales of the SLEAQ

Research Question #1

> *Is a science learning environment and attitude questionnaire valid when used with primary science students in Singapore?*

It was necessary to determine whether the SLEAQ, developed for use by primary science students for the present study, was valid and reliable. To do this, a number of statistical analyses were conducted. Students' responses were analysed to furnish evidence regarding the factor structure, scale internal consistency reliability, and each learning environment scale's ability to differentiate between students in different classrooms. Both item and factor analyses were conducted. Principal axis factoring with varimax rotation and Kaiser normalisation was used to determine the structure of the seven scales in the SLEAQ for the whole sample of 485 students using the individual student as the unit of analysis. A separate analysis was conducted for the actual and preferred versions of the SLEAQ. The criteria for the retention of any item were that it must have a loading of at least 0.40 on its own scale and less than 0.40 on all other scales.

The Cronbach alpha coefficient was computed for each of the scales in the SLEAQ as an estimate of the internal consistency reliability. The discriminant validity of each scale was determined by calculating the mean correlation of each scale with the other scales. These analyses were performed at both the individual student and the class levels of analysis.

An analysis of variance (ANOVA) with class membership as the independent variable was used to determine the ability of each learning environment scale in the actual form of SLEAQ to differentiate between the perceptions of students in different classes. The eta^2 statistic (the ratio of 'between' to 'total' sums of squares) was used to describe the proportion of variance in the learning environment scale scores accounted for by class membership.

3.6.2 Differences Between Students' Perceptions of Actual and Preferred Learning Environment

Research Question #2

Are there differences between students' perceptions of actual and preferred learning environments?

The use of separate actual and preferred learning environment instruments has permitted the investigation of differences between students' perceptions of the actual classroom environment and that preferred by students. Past research into difference between forms has found that, generally, students prefer a more positive classroom environment than is actually present (Fisher & Fraser, 1983a; Fraser, 2012).

The present study examined student perceptions of the actual and preferred learning environment in their primary science classes. To investigate the difference between students' perceptions of the actual and preferred learning environment, students' responses to the two forms (placed side-by-side on a single form) were matched. These two sets of responses were then compared using a one-way MANOVA with repeated measures and using the individual students as the unit of analysis. The set of learning environment scales in the SLEAQ constituted the dependent variables and the form of the questionnaire (actual/preferred) was the repeated measures factor. Because the multivariate test using Wilks' lambda criterion yielded statistically significant differences for the set of five learning environment scales as a whole, the univariate ANOVA results were interpreted separately for each individual learning environment scale.

3.6.3 Sex Differences in Learning Environment Perceptions and Attitudes

Research Question #3

> *Are perceptions of the learning environment and attitudes different for students of different sexes?*

Over the past two decades, numerous researchers have studied the topic of sex difference in education (Parker & Rennie, 2002; Scantlebury, 2012). To examine sex differences in classroom environment perceptions in the present study, data were analysed using a one-way MANOVA with the student as the unit of analysis. Sex was the independent variable and the actual learning environment scales, the preferred learning environment scales and the attitude scales formed the set of dependent variables. Because the multivariate test using Wilks' lambda produced statistically significant results, the univariate ANOVA results were interpreted for each dependent variable.

3.6.4 Associations Between Students' Attitudes and the Nature of Classroom Learning Environment

Research Question #4

> *Is there a relationship between student perceptions of the learning environment and their attitudes?*

One of the strongest traditions in past classroom environment research has involved investigation of associations between students' cognitive and affective learning outcomes and their perceptions of the learning environment (Fraser 1998a, 2012).

Numerous studies have shown that students' perceptions of the learning environment can account for appreciable amounts of variance in learning outcomes, often beyond that attributable to student background characteristics. In the present study, associations between student attitudes and aspects of the learning environment as assessed with the SLEAQ were investigated. To investigate associations between student attitudes and the nature of the learning environment, simple correlation and multiple regression analyses were conducted using the individual student as the unit of analysis. The simple correlation (r) describes the bivariate association between each of the five learning environment scales and each attitude outcome. The multiple correlation (R) describes the relationship between an attitudinal outcome and the set of learning environment scales. The standardised regression weight (β) describes the association between a particular learning environment scale and an outcome when all other learning environment scales are mutually controlled.

3.7 Summary

The present study is one of only a few learning environment studies to be conducted at the primary level in Singapore. As such, the study was largely an exploratory one, lending itself to more quantitative research methods.

The questionnaire developed for this study – Science Learning Environment and Attitude Questionnaire (SLEAQ) – consisted of two parts, with one section consisting of items which assess the science learning environment and the other section made up of items which assess attitudinal outcomes.

After careful consideration of a number of learning environment questionnaires, I selected three scales (Involvement, Investigation and Cooperation) from the What Is Happening In this Class? (WIHIC) and one scale (Student Negotiation) from the Constructivist Learning Environment Survey (CLES) to be included in the science learning environment section of the SLEAQ. An additional scale of Connection, developed for this study, was also included. Two scales (Attitude to Scientific Inquiry and Enjoyment of Science Lessons) from the Test of Science-Related Attitudes (TOSRA) were included in the SLEAQ to assess students' attitudes towards science.

An important next step in the development of the SLEAQ was a pilot test that included 40 primary 5 students. In the first place, the pilot study was used to examine how long it took students to complete the questionnaire and to ensure that instructions were clear. Secondly, the researcher wanted to ensure that the individual items of the SLEAQ were clear and unambiguous and that respondents comprehended them in the way in which the researcher intended. To do this, the researcher asked respondents to identify items which were unclear and these were discussed and clarified during the interviews that followed. In addition, the researcher asked students to explain why they had responded to items in a particular way and, where possible, provide examples. Based on the pilot test, it was found that students took approximately 30 minutes to complete both the actual and preferred versions of the SLEAQ, and some minor revisions to wording were made to items for which the meaning appeared ambiguous.

The final version of the SLEAQ was administered to 485 students in 16 classes from four co-educational primary schools. Administration took place during the last semester of the academic year, with students responding to both the actual and the preferred versions at the same sitting. In all cases, the researcher administered the questionnaires personally to ensure confidentiality of responses and consistency of administrative procedures.

The data collected were analysed to answer the research questions outlined in Chapter 1. A major thrust of the present study was to explore the validity and reliability of the SLEAQ for use in Singapore at the primary level. To determine whether the SLEAQ was valid and reliable, the factor structure, scale internal consistency reliability and ability to differentiate between students in different classrooms were examined.

Another research question involved differences between students' perceptions of their actual and preferred learning environment in their primary science classes. Data were analysed using a one-way MANOVA with repeated measures and using the individual students as the unit of analysis. The set of learning environment scales in the SLEAQ constituted the dependent variables and the form of the questionnaire (actual/preferred) was the repeated measures factor. Because the multivariate test using Wilks' lambda criterion yielded statistically significant differences for the set of five learning environment scales as a whole, the univariate ANOVA results were interpreted separately for each individual learning environment scale.

A further research question involved sex differences in students' perceptions of the learning environment and attitudes towards their science classes. Data were analysed with a one-way MANOVA with the student as the unit of analysis. Sex was the independent variable and the actual learning environment scales, the preferred learning environment scales and the attitude scales formed the set of dependent variables. Because the multivariate test using Wilks' lambda produced statistically significant results, the univariate ANOVA results were interpreted for each dependent variable.

The last research question involved outcome–environment relationships. To examine whether relationships between student attitudes and their perceptions of the learning environment, simple correlation and multiple regression analyses were calculated using the individual student as the unit of analysis.

The following chapter reports the findings and results for the analyses of the data.

Chapter 4

ANALYSES AND RESULTS

4.1 Introduction

This chapter is devoted to reporting the findings of the present study. The study made use of a new Science Learning Environment and Attitude Questionnaire (SLEAQ), consisting of 7 scales made up of 50 items, that was largely modified from scales in existing instruments that were considered relevant to the teaching and learning of science as inquiry. As described in Section 3.3, the SLEAQ consists of the three scales of Involvement (8 items), Investigation (8 items) and Cooperation (8 items) which had their origins in the What Is happening In this Class? (WIHIC), one scale of Student Negotiation (6 items) from the Constructivist Learning Environment Survey (CLES), one scale of Connection (8 items) which was developed for this study, and the two scales of Attitude to Scientific Inquiry (6 items) and Enjoyment of Science Lessons (6 items) that were adapted from the Test of Science-Related Attitudes (TOSRA). In summary, the SLEAQ assesses:

- Involvement – the extent to which students are engaged in asking questions.
- Investigation – the extent to which students are engaged in the process of inquiry where they are involved in investigating to find evidence for their questions.
- Cooperation – the extent to which students cooperate rather than compete with one another on learning tasks.
- Student Negotiation – the extent to which students explain and communicate their ideas to their teacher and friends.
- Connection – the extent to which students are able to make connections of what they have learnt and apply to their daily experiences.
- Attitude to Scientific Inquiry – the extent to which students are inclined towards the learning of science.
- Enjoyment of Science Lessons – the extent to which students enjoy science as a subject.

The readability level of the SLEAQ was checked to suit the primary-school level and a single response format to the questionnaire was used to reduce confusion during the administration. Actual and preferred versions of the SLEAQ were also developed to find out students' perceptions of their actual and preferred classrooms. The SLEAQ was administered to 485 primary school students aged 11 to 12 years old from 16 classes selected from four different co-educational schools in Singapore. This target group was chosen because it comprised graduating students who would have substantial experience in their science lessons and therefore could provide valuable information about the types of learning environments that they had experienced.

This chapter provides the results of various analyses that were conducted to answer the study's research questions, which were delineated in Section 1.4, using the following headings:

- Validity and Reliability of the Learning Environment and Attitude Scales of the SLEAQ (Section 4.2);
  - Factor Analysis of Learning Environment Scales (Section 4.2.1)
  - Factor Analysis of Attitude Scales (Section 4.2.2)
  - Internal Consistency Reliability (Section 4.2.3)
  - Ability to Differentiate Between Classrooms (Section 4.2.4)
- Differences Between Students' Perceptions of Actual and Preferred Learning Environment (Section 4.3)
- Sex Differences in Learning Environment Perceptions and Attitudes (Section 4.4)
- Associations Between Students' Attitudes and the Nature of Classroom Learning Environment (Section 4.5)
- Summary (Section 4.6).

4.2 Validity and Reliability of the Learning Environment and Attitude Scales of the SLEAQ

The SLEAQ involved adopting and adapting relevant dimensions and items from widely-used classroom learning environment questionnaires, namely, the WIHIC

(Aldridge & Fraser, 2000) and CLES (Aldridge, Fraser, Taylor, & Chen, 2000; Taylor, Fraser, & Fisher, 1997). TOSRA (Fraser, 1981) provided a source of attitude scales. A parallel preferred version of classroom learning environment scales was also developed to accompany the actual version. Before the instrument was used in the present study, it was important to ensure its suitability for use at the primary-school level. The questionnaire was pilot-tested with one class of Primary 5 science students, with selected students subsequently being interviewed about the clarity and the readability of the items and the item-response format, before it was administered to 485 students in the main study. A more detailed description of the SLEAQ can be found in Section 3.3.

At the end of the study, 485 questionnaire responses with completed data were identified. The data collected from this group of students were then analysed to provide statistical validation to answer the first research question:

Research Question #1

> *Is a science learning environment and attitude questionnaire valid when used with primary science students in Singapore?*

As noted in Section 3.3, the SLEAQ contains scales that assess the conceptually-distinct constructs of classroom learning environment and students' attitudes to science, but these scales were assembled into a single questionnaire with a common set of instructions and a single response format to reduce administration time, fatigue and possible confusion among students. However, it was appropriate that separate analyses of conceptually-distinct learning environment and attitude data were conducted to determine the validity and reliability of the scales. These included: factor structure (Sections 4.2.1 and 4.2.2); internal consistency reliability (Section 4.2.3); and the ability to differentiate between classrooms (Section 4.2.4).

4.2.1 Factor Analysis of Learning Environment Scales

As a first step, item and factor analyses were conducted to identify those items whose removal would improve the internal consistency reliability and factorial validity of the learning environment scales in the SLEAQ. A principal axis factoring with varimax rotation and Kaiser normalisation was used to check the structure of the 38-item five-scale version of the learning environment scales for the whole sample of 485 students using the individual student as the unit of analysis. A separate analysis was conducted for the actual and preferred versions.

Table 4.1 shows the factor loadings obtained for the whole sample of 485 students in 16 classes from four schools for the actual and preferred forms of the learning environment scales in the questionnaire. The criteria for the retention of any item were that it must have a loading of at least 0.40 on its own scale and less than 0.40 on all other scales.

These two criteria were satisfied except for the following items, which were omitted in order to improve the internal consistency reliability and factorial validity of the instrument:

- Involvement 3: My teacher asks me questions.
- Involvement 6: I explain my ideas to other students.
- Involvement 7: Students discuss with me how to go about solving problems.
- Investigation 2: I am asked to think about the evidence for statements.
- Investigation 4: I explain the meaning of statements, diagrams and graphs.
- Student Negotiation 1: I get the chance to talk to other students.

The bottom of Table 4.1 shows the percentage of variance for the actual version of the different learning environment scales ranged between 3.90% and 33.99% and for the preferred version ranged between 3.39% and 38.37%. The total percentage variance was 55.94% and 58.72% for the actual and preferred versions, respectively. Eigenvalues ranged between 1.28 and 11.21 for the actual version and from 1.12 and 12.87 for the preferred version for different scales.

Table 4.1 **Factor Analysis Results for Actual and Preferred Forms of Learning Environment Scales**

Item No	Involvement		Investigation		Cooperation		Student Negotiation		Connection	
	Act	Pref	Act	Pref	Act	Pref	Act	Pref	Act	Pref
Involv 1	0.53	0.52								
Involv 2	0.70	0.66								
Involv 4	0.46	0.46								
Involv 5	0.42	0.44								
Involv 8	0.40	0.51								
Invest 1			0.54	0.54						
Invest 3			0.89	0.62						
Invest 5			0.61	0.56						
Invest 6			0.74	0.63						
Invest 7			0.72	0.69						
Invest 8			0.62	0.61						
Coope 1					0.72	0.68				
Coope 2					0.65	0.61				
Coope 3					0.62	0.63				
Coope 4					0.66	0.68				
Coope 5					0.51	0.52				
Coope 6					0.74	0.65				
Coope 7					0.72	0.68				
Coope 8					0.59	0.55				
St Neg 2							0.42	0.48		
St Neg 3							0.44	0.56		
St Neg 4							0.68	0.63		
St Neg 5							0.57	0.52		
St Neg 6							0.59	0.64		
Conne 1									0.71	0.71
Conne 2									0.75	0.73
Conne 3									0.68	0.69
Conne 4									0.64	0.62
Conne 5									0.47	0.62
Conne 6									0.43	0.61
Conne 7									0.54	0.57
Conne 8									0.50	0.58
% Variance	3.90	3.73	6.49	6.03	33.99	7.20	4.63	3.39	6.93	38.37
Eigenvalue	1.28	1.23	2.14	1.99	11.21	2.38	1.53	1.12	2.28	12.87

N = 485 students in 16 classes.
Factor loadings less than 0.40 have been omitted from the table.
Principal axis factoring with varimax rotation and Kaiser Normalisation.

The factor analysis supported the 32-item five-scale structure of both versions of the SLEAQ. In terms of factor structure of the WIHIC scales, the results of this study replicate previous research: in the USA by Allen and Fraser (2007) with 520 Grade 4 and 5 students and 120 of their parents; in India by Koul and Fisher (2005) with 1,021 students in 31 science classes; in Australia and Taiwan by Aldridge, Fraser and Huang (1999) with a sample of 1,081 students in Australia and 1,879 students in

Taiwan; in Singapore by Chionh and Fraser (2009) with a sample of 2,310 Grade 10 geography and mathematics students; in South Africa by Aldridge, Fraser and Ntuli (2009) with 1,077 grade 4–7 students; in Korea by Kim, Fisher and Fraser (2000) with 543 Grade 8 science students; in Indonesia by Wahyudi and Treagust (2004) with 1,400 lower-secondary science students; in the United Arab Emirates by MacLeod and Fraser (2010) with 763 college students; and in Australia, UK and Canada by Dorman (2003) with 3,980 high school students.

4.2.2 Factor Analysis of Attitude Scales

The original TOSRA (Fraser, 1981) consisted of 70 items designed to measure seven distinct science-related attitudes among secondary school pupils. However, for the purpose of this study, only the two scales of Attitude to Inquiry and Enjoyment of Science Lessons were used. For these two attitude scales selected for use in the SLEAQ, all the positively-worded items in these scales were selected. In addition, one of the negatively-worded items was chosen from each of the two scales and rewritten as a positively-worded item so as to minimise the probability of misinterpretation.

A similar principal axis factor analysis with varimax rotation and Kaiser normalisation was also used to check the structure of the attitude scales using the individual student as the unit of analysis. The same criteria for the retention of any item were used: it must have a factor loading of at least 0.40 on its own scale and less than 0.40 on all other scales. Table 4.2 shows the factor loadings obtained for the attitude scales in the SLEAQ.

All of the attitude items had a loading of at least 0.40 on their *a priori* scale, and less than 0.40 on the other scale, for the two scales of Attitude to Inquiry and Enjoyment of Science Lessons as indicated in Table 4.2. The percentage of variance was 25.09% and 45.92% for the two scales, with a total variance accounted for 71.01%. Eigenvalues were 3.01 and 5.51, respectively. Based on the factor analysis, all items on the two scales were retained.

Overall, the TOSRA scales used in my study demonstrated sound factorial validity. This study also replicates the validity results reported with the original and modified versions of the TOSRA when used in previous studies, such as Fraser, Aldridge and Adolphe (2010) with 1,161 students in Indonesia and Australia, in Martin-Dunlop and Fraser (2008) with 525 female university science students in USA, and Wong and Fraser (1996) with 1,592 grade 10 chemistry students in Singapore.

Table 4.2 Factor Analysis Results for Attitude Scales in the SLEAQ

Item No	Attitude to Inquiry	Enjoyment of Science Lessons
Attitude to Inquiry 1	0.73	
Attitude to Inquiry 2	0.78	
Attitude to Inquiry 3	0.79	
Attitude to Inquiry 4	0.75	
Attitude to Inquiry 5	0.71	
Attitude to Inquiry 6	0.60	
Enjoyment 1		0.80
Enjoyment 2		0.84
Enjoyment 3		0.83
Enjoyment 4		0.92
Enjoyment 5		0.91
Enjoyment 6		0.87
% Variance	25.09	45.92
Eigenvalue	3.01	5.51

N = 485 students in 16 classes.
Principal axis factoring with varimax rotation and Kaiser normalisation.

4.2.3 Internal Consistency Reliability

The internal consistency reliabilities of the learning environment and attitude scales were also checked using Cronbach's alpha coefficient for two units of analysis (the individual and the class mean) to determine the extent to which items in each SLEAQ scale measured the same construct.

Table 4.3 indicates that, for the learning environment scales in the actual version of the SLEAQ, scale reliabilities ranged from 0.71 to 0.89 using the individual as the unit of analysis and from 0.86 to 0.98 using the class mean as the unit of analysis. For the learning environment scales in the preferred version of the SLEAQ, scale reliabilities ranged from 0.78 to 0.89 using the individual as the unit of analysis and from 0.90 to 0.97 using the class mean as the unit of analysis.

For the student attitude scales of the SLEAQ, the scale reliability estimates indicated in Table 4.3 were 0.88 and 0.95 using the individual as the unit of analysis and were 0.91 and 0.99 using the class mean as the unit of analysis.

These values in Table 4.3 suggest high internal consistency reliability for all the scales and more than satisfy the recommended level of 0.7 (Nunnally, 1978). Overall, the SLEAQ appears to be reliable when used in Singaporean primary science classrooms.

Table 4.3 **Average Item Mean, Average Item Standard Deviation, Internal Consistency Reliability (Alpha Coefficient) and Ability to Differentiate Between Classrooms (ANOVA Results) for Learning Environment and Attitude Scales**

Scale	No of Items	Unit of Analysis	Average Item Mean		Average Item SD		Alpha Reliability		Eta²
			Act	Pref	Act	Pref	Act	Pref	Act
Learning Environment									
Involvement	5	Individual	3.03	3.68	0.65	0.71	0.71	0.78	0.15**
		Class	3.03	3.66	0.25	0.29	0.86	0.90	
Investigation	6	Individual	2.91	3.79	0.84	0.81	0.86	0.88	0.16**
		Class	2.90	3.77	0.33	0.28	0.95	0.96	
Cooperation	8	Individual	3.81	4.41	0.77	0.62	0.89	0.89	0.21**
		Class	3.78	4.40	0.36	0.24	0.98	0.96	
Student	5	Individual	3.45	4.06	0.77	0.72	0.83	0.84	0.16**
Negotiation		Class	3.44	4.04	0.32	0.26	0.95	0.95	
Connection	8	Individual	3.96	4.48	0.69	0.58	0.87	0.89	0.15**
		Class	3.95	4.47	0.28	0.23	0.96	0.97	
Attitudes									
Attitude to Inquiry	6	Individual Class	4.03 4.01		0.83 0.23		0.88 0.91		
Enjoyment of Science Lessons	6	Individual Class	3.59 4.24		1.09 0.49		0.95 0.99		

N=485 students in 16 classes.
***p*<0.01
Eta² is the ratio of between to total sums of square and represents the proportion of variance accounted for by class membership.

4.2.4 Ability to Differentiate Between Classrooms

As further evidence of the validity of the learning environment scales in SLEAQ, an analysis of variance (ANOVA) with class membership as the independent variable was used to determine the ability of each scale in the actual form of SLEAQ to differentiate between the perceptions of students in different classes. The ANOVA results, presented in the final column in Table 4.3, indicate the amount of variance accounted for by classroom membership (eta^2 statistic) and whether differences between classes were statistically significant. Differences were statistically significant ($p<0.01$) for all the learning environment scales, with the eta^2 statistic, which is a measure of the degree of association between class membership and the dependent variable for each of the learning environment scales, ranged from 0.15 to 0.21.

All the five learning environment scales in the SLEAQ were able to differentiate between the 16 science classrooms.

4.3 Differences Between Students' Perceptions of Actual and Preferred Learning Environment

During the collection of data, all students completed a questionnaire to determine their perceptions of their actual classroom environment. At the same time, students also completed a parallel questionnaire related to their preferred or ideal classroom environment. The actual and the preferred response scales of the SLEAQ items were placed side-by-side on a single form of the questionnaire to provide a more economical format (Aldridge & Fraser, 2008). The actual form was used to assess students' perceptions of the existing learning environment, whilst the preferred form was used to assess the type of learning environment that students would prefer. Appendix A contains a copy of the SLEAQ and illustrates this side-by-side response format. These two forms were used to determine whether differences existed in students' perceptions to answer the second research question:

Research Question #2

> *Are there differences between students' perceptions of actual and preferred learning environments?*

To examine differences between students' perceptions of the actual and preferred classroom environment, students' responses to the actual and preferred versions of the learning environment scales in the SLEAQ were compared using a one-way MANOVA with repeated measures and using the individual students as the unit of analysis. The set of learning environment scales in the SLEAQ constituted the dependent variables and the form of the questionnaire (actual/preferred) was the repeated measures factor. Because the multivariate test using Wilks' lambda criterion yielded statistically significant differences for the set of five learning environment scales as a whole, the univariate ANOVA results were interpreted separately for each individual learning environment scale. Table 4.4 provides those ANOVA results, including the statistical significance of actual–preferred differences.

Given that the number of items in different learning environment scales differ, the average item mean, or the scale total divided by the number of items in that scale, was used to provide a meaningful comparison between scales. Table 4.4 reports the average item mean and average item standard deviation for scores for the actual and preferred versions of the learning environment scales in the SLEAQ.

Table 4.4 **Average Item Mean, Average Item Standard Deviation and Difference (Effect Size and Results of MANOVA for Repeated Measures) between Actual and Preferred Scores on Each Learning Environment Scale in SLEAQ**

Scale	No of Items	Mean		SD		Difference	
		Actual	Preferred	Actual	Preferred	Effect Size (*d*)	*F*
Involvement	5	3.03	3.68	0.65	0.71	0.95	635.06***
Investigation	6	2.91	3.79	0.84	0.81	1.07	844.02***
Cooperation	8	3.81	4.41	0.77	0.62	0.86	590.73***
Student Negotiation	5	3.45	4.06	0.77	0.72	0.81	509.07***
Connection	8	3.96	4.48	0.69	0.58	0.81	535.28***

N=485 students in 16 classes.
****p*<0.001
d is the difference between two means divided by the pooled standard deviation.

In order to estimate the magnitude of the differences or educational importance between scores on the actual and preferred versions, in addition to their statistical significance, effect sizes (the difference between two means divided by the pooled standard deviation) were calculated as recommended by Thompson (1998a, 1998b). An effect size, which is calculated by dividing the difference between the mean score on the actual and preferred versions of the learning environment scales in the SLEAQ by the pooled standard deviation, expresses actual and preferred differences in standard deviation units. According to Cohen (1988), effect sizes of 0.20 can be considered small, of 0.50 can be considered medium and of 0.80 can be considered large. Table 4.4 also indicates the effect size for the difference between the actual and preferred versions for each learning environment scale.

Table 4.4 reveals that the effect size for actual–preferred differences for each of the learning environment scale in the SLEAQ ranged from 0.81 to 1.07 standard deviations. According to the criteria recommended by Cohen (1998), these effect sizes all are large. Furthermore, there was a statistically significant difference ($p<0.001$) between actual and preferred scores for each learning environment scale in the SLEAQ.

Student responses to the actual and preferred forms were also used to generate graphical profiles of students' perceptions of their actual and preferred learning environments. Figure 4.1 graphically illustrates that the average item mean for all the learning environment scales in the SLEAQ exceeded the value of 2.5, indicating that students perceived the activities to occur on average with a frequency between 'sometimes' to 'often'. Although it can be seen that students generally had positive perceptions of their science classrooms, they would prefer the learning environment to be even more positive across all dimensions. These results are consistent with previous studies conducted by Fraser (1998a), Fisher and Fraser (1983a) and Henderson, Fisher and Fraser (2000) that showed that students preferred a classroom environment that was more favourable than the one which they perceived as actually being present. This finding has important practical implications for teachers teaching in the primary science classrooms.

According to the average item means of above 4 in Figure 4.1, students preferred activities associated with the learning environment items in SLEAQ to occur 'often' for Cooperation, Student Negotiation and Connection scales. Also, students preferred the activities encompassed by the Involvement and Investigation scales to occur approximately 'sometimes' (average item mean of 3). However, Figure 4.1 also shows that the level of each learning environment dimension perceived to be actually present was lower for every scale. The highest average item mean in Figure 4.1 occurred for actual Connection and the lowest average item mean occurred for actual Investigation. Improving the level of classroom Investigation appeared to be a high priority in these primary science students' opinions.

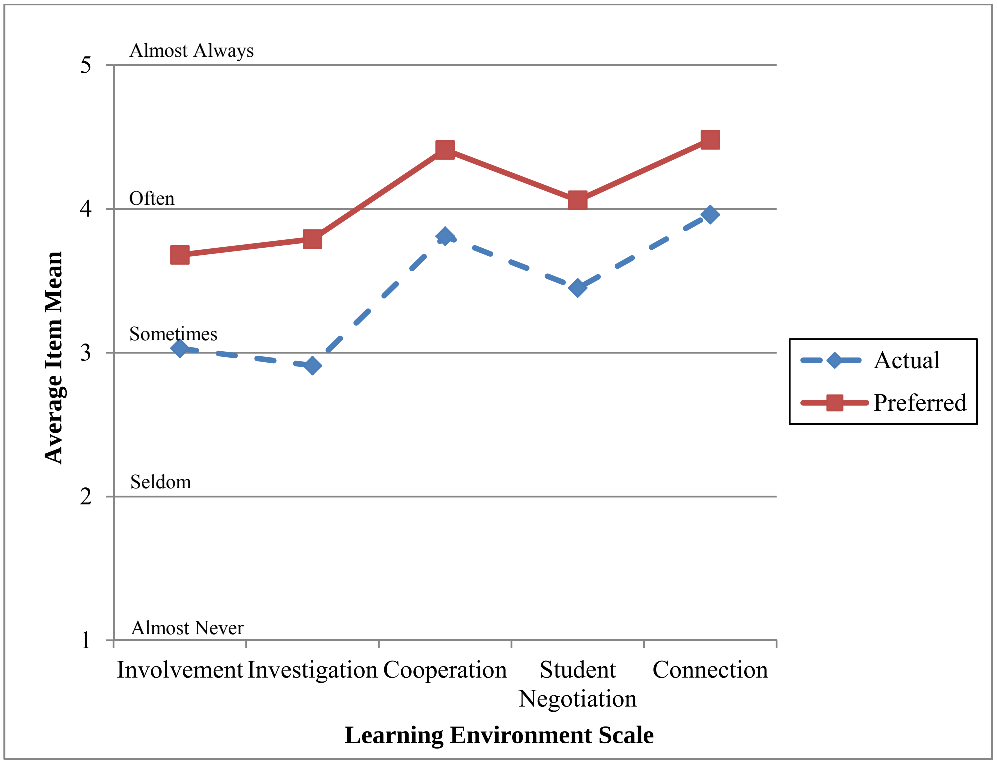

Figure 4.1 **Differences between Students' Perceptions of Actual and Preferred Learning Environment**

4.4 Sex Differences in Learning Environment Perceptions and Attitudes

This section reports the differences and similarities between male and female students in their perceptions of the learning environment and their attitudes towards their science classes. Analyses involving MANOVAs and *F* tests were used to answer the third research question:

Research Question #3

> *Are perceptions of the learning environment and attitudes different for students of different sexes?*

Sex differences in classroom environment perceptions and attitudes were investigated using a one-way MANOVA with the student as the unit of analysis. Sex was the independent variable and the actual learning environment scales, the preferred learning environment scales and the attitude scales formed the set of dependent variables. Because the multivariate test using Wilks' lambda was statistically significant, the univariate ANOVA results were interpreted for each dependent variable in Table 4.5.

Table 4.5 reports sex differences in terms of the average item mean for scores on each learning environment for both the actual and preferred versions and the attitude scales of the SLEAQ. *F* ratios are also indicated in the last column of Table 4.5 to show the statistical significance of sex differences. Effect sizes, calculated by dividing the difference between the males' and females' means by the pooled standard deviation are also shown in Table 4.5.

Table 4.5 Average Item Mean, Average Standard Deviation and Sex Difference (Effect Size and Results of MANOVA) for Learning Environment and Attitude Scales

Scale		Average Item Mean		Average Item SD		Difference	
		Male	Female	Male	Female	Effect Size (*d*)	*F*
Learning Environment							
Involvement	Actual	3.13	2.92	0.62	0.65	-0.33	13.03**
	Preferred	3.73	3.62	0.71	0.72	-0.15	2.94
Investigation	Actual	2.91	2.91	0.82	0.86	0.01	0.03
	Preferred	3.77	3.81	0.81	0.82	0.04	0.30
Cooperation	Actual	3.68	3.96	0.78	0.72	0.37	16.45**
	Preferred	4.31	4.53	0.65	0.57	0.36	16.00**
Student Negotiation	Actual	3.41	3.50	0.79	0.75	0.12	1.46
	Preferred	4.01	4.50	0.73	0.71	0.15	2.86
Connection	Actual	3.97	3.94	0.66	0.72	0.04	0.32
	Preferred	4.50	4.45	0.54	0.64	-0.08	0.81
Attitudes							
Attitude to Inquiry		3.96	4.10	0.83	0.82	0.16	3.04
Enjoyment of Science Lessons		3.74	3.42	1.02	1.12	-0.29	10.73**

**$p < 0.01$
males (n = 256); females (n = 229)

Table 4.5 shows that, relative to females, male students perceived significantly (p<0.01) more actual Involvement and less actual Cooperation and preferred significantly less Cooperation. The effect sizes for sex differences for these scales were -0.33 standard deviations (actual Involvement), 0.37 (actual Cooperation) and 0.36 (preferred Cooperation), suggesting a relatively small difference between the sexes (using Cohen's criteria) for the learning environment scales of Involvement and Cooperation.

Sex differences in student attitudes were also explored. The results reported in Table 4.5 suggest that male and female students had similar Attitude to Inquiry scores and that sex differences were statistically nonsignificant. However, male students reported significantly ($p<0.01$) greater Enjoyment of their Science Lessons as compared to their female counterparts. The effect size for sex differences in Enjoyment of Science Lessons was -0.29 standard deviations.

The means generated using male and female scores on each actual learning environment and attitude scale were used to draw the graphical profile provided in Figure 4.2. This figure illustrates that males had higher average item means than females for Involvement and Connection, whereas females had higher average item means than males for Cooperation and Student Negotiation.

Comparing Figures 4.1 and 4.2, it can be seen that the magnitudes of differences were much larger for actual–preferred differences than for sex differences. Table 4.4 and 4.5 confirms that effect sizes ranged from 0.81 to 1.07 standard deviations for actual–preferred differences (large), but ranged from only 0.01 to 0.37 standard deviations for sex difference for actual learning environments (small using Cohen's criteria).

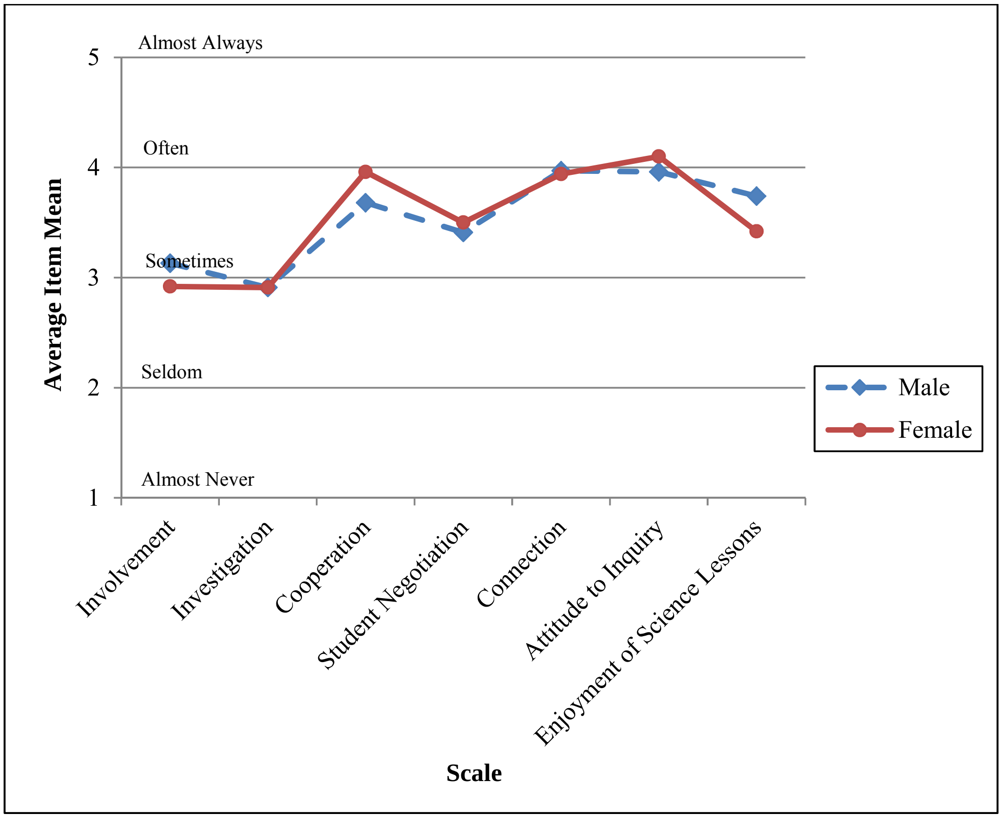

Figure 4.2 **Differences between Male and Female Students' Scores on the Actual Learning Environment Scales and Attitudes Scales of SLEAQ**

4.5 Associations Between Students' Attitudes and the Nature of Classroom Learning Environment

This section reports the strength and statistical significance of associations between the nature of the classroom learning environment and students' attitudes. Analyses involving simple correlation and multiple regression analyses were undertaken to answer the fourth research question:

Research Question #4

Is there a relationship between student perceptions of the learning environment and their attitudes?

The results of the simple correlation analysis in Table 4.6 reveal that each learning environment scale was significantly (p<0.01) and positively correlated with both Attitude to Inquiry and Enjoyment of Science Lessons. The correlations for Attitude to Inquiry ranged from 0.29 (Student Negotiation) to 0.45 (Involvement). For Enjoyment of Science Lessons, the correlations ranged from 0.25 (Cooperation) to 0.53 (Connection). The results of the simple correlation analysis suggest that improved student attitudes were associated with more emphasis on all of the aspects of the learning environment scales assessed in the SLEAQ.

Multiple regression analysis was undertaken using the set of five learning environment scales of the SLEAQ as independent variables and an attitude scale as the dependent variable. This analysis provides more parsimonious information about relationships between correlated independent variables and reduces the risk of a Type I error often linked with simple correlation analysis. Multiple regression analyses were performed using the individual student as the unit of analysis. The multiple correlation (R) reported in Table 4.6 for the set of learning environment scales was 0.39 for Attitude to Inquiry and 0.57 for Enjoyment of Science Lessons, and was statistically significant ($p<0.01$) in each case.

To identify which learning environment scales contributed most to the variance in student satisfaction, the multiple regression coefficient (β) was examined for each scale. The regression coefficients in Table 4.6 showed that Connection was a significant independent predictor to Attitude to Inquiry, whereas Involvement, Cooperation and Connection were significant independent predictors of Enjoyment of Science Lessons. These results suggest that the more Connection there is in a science classroom, the more likely it is that learners have a positive Attitude to Inquiry. Students would also have greater Enjoyment of Science Lessons if there is more Involvement, Cooperation and Connection.

Overall, the results in Table 4.6 suggest that student attitudes were consistently more positive in classes perceived to have higher learning environment scores. These results replicate the findings of past studies, reviewed by Fraser (2012), that generally indicate consistent associations between student attitudes and dimensions of the classroom environment.

Table 4.6 **Simple Correlation and Multiple Regression Analyses for Associations between Attitude and Learning Environment Scales**

Environment Scale	Attitude to Inquiry		Enjoyment of Science Lessons	
	r	β	*r*	β
Involvement	0.45**	0.03	0.42**	0.23**
Investigation	0.32**	0.15	0.35**	0.07
Cooperation	0.31**	0.10	0.25**	0.10*
Student Negotiation	0.29**	0.03	0.31**	0.04
Connection	0.33**	0.16**	0.53**	0.46**
Multiple Correlation, *R*		0.39**		0.57**

N=485 students in 16 classes.
*$p<0.05$, **$p<0.01$

4.6 Summary

This chapter reported the findings of a study into students' perceptions of their actual and preferred learning environments at the primary level in Singapore. The Science Learning Environment and Attitude Questionnaire (SLEAQ) was administered to a sample of 640 primary science students in 16 classes across 4 schools. Faulty responses, which included multiple responses, skipped entries or incomplete returns from parents about allowing their child to take part in the study, were discarded, resulting in the sample size going down to 485 participants. The SLEAQ, which is made up of 7 scales with a total of 44 items, includes scales from the What Is Happening In this Class? (WIHIC), Constructivist Learning Environment Survey (CLES) and Test of Science-Related Attitudes (TOSRA).

The chapter began with a restatement of the purposes of the study, which aimed to (a) develop and validate the SLEAQ for use by primary science students in Singapore and to investigate (b) differences between students' perceptions of their actual and preferred learning environments, (c) sex difference in learning environment and attitudes to science and (d) associations between the learning environment and students' attitudes.

The first research objective was concerned with the validity and the reliability of the SLEAQ (a combination of the WIHIC, CLES and TOSRA scales with slight modifications) in terms of its factor structure, internal consistency reliability and ability to differentiate between classrooms.

Factor analyses of the learning environment scales in the SLEAQ using principal axis factor analysis with varimax rotation and Kaiser normalisation supported the suitability of their structure for use in Singapore primary science classrooms in both their actual and preferred versions. The factor loadings for the sample of 485 students from the 16 classes in 4 schools supported a 32-item five scale structure for the SLEAQ using the individual student as the unit of analysis. The criteria set for the retention of any item were that it had to have factor loadings of at least 0.40 on its own scale and less than 0.40 on all of the other scales. All but six items from the learning environment scales were retained. The factor analysis showed that the percentage of variance ranged between 3.90% and 33.99% for the actual version of different learning environment scales of the SLEAQ and between 3.39% and 38.37% for the preferred version. The total percentage variance was 55.94% and 58.72% for the actual and preferred versions, respectively. Eigenvalues ranged between 1.28 and 11.21 for the actual version and from 1.12 and 12.87 for the preferred version for the different learning environment scales.

A similar principal axis factor analysis with varimax rotation and Kaiser normalisation was also used to check the structure of the attitude scales using the individual student as the unit of analysis. The percentage of variance was 25.09% (Attitude to Inquiry) and 45.92% (Enjoyment of Science Lessons), with a total variance accounted for 71.01%. All items in both the attitude scales were retained because they satisfied the criteria that they have factor loadings of at least 0.40 on their own scale and less than 0.40 on all of the other scales.

The internal consistency reliability estimate (Cronbach alpha coefficient) for each of the learning environment and attitudes scales of the SLEAQ, using both the individual and the class mean as the unit of analysis, was also checked. Results showed high internal consistency reliability for all of the scales above the recommended level of 0.7 (Nunnally, 1978).

The results from analysis of variance (ANOVA) also suggested that each actual learning environment scale in the SLEAQ could differentiate between the perceptions of students in the 16 different science classrooms. The eta^2 statistic, which is an estimate of the strength of association between class membership and the scores from the learning environment scales, ranged from 0.15 to 0.21. All of the five learning environment scales differentiated significantly ($p<0.01$) between classrooms. Overall, the validation information provides support for the confident future use of the SLEAQ in Singaporean primary science classrooms.

The second research objective was to determine whether differences exist between students' perceptions of actual and preferred learning environments. A one-way MANOVA with repeated measures revealed statistically significant differences between students' perceptions of their actual learning environment and the one that they would prefer for all five learning environment scales using the individual student as the unit of analysis. Students preferred more of each of the learning environment dimensions in the SLEAQ, with Investigation having the largest difference between the actual and preferred scores. Effect sizes for the five scales of the learning environment scales in the SLEAQ (calculated to provide an approximation of the magnitude of differences between students' responses to the actual and preferred versions) ranged from 0.81 to 1.07 standard deviations. This pattern of results is consistent with research by Fraser (1998a), Fisher and Fraser (1983a) and Henderson, Fisher and Fraser (2000). These large discrepancies between the actual classroom environment and what is preferred by students have important pedagogical implications for primary science teachers in Singapore.

The third research objective involved whether students of different sexes perceived the learning environment differently and held different attitudes. A one-way MANOVA, using the student as the unit of analysis, revealed that male students perceived significantly ($p<0.01$) more actual Involvement and less actual Cooperation and preferred significantly less Cooperation. The effect sizes for sex differences for these scales were -0.33 standard deviations (actual Involvement), 0.37 (actual Cooperation) and 0.36 (preferred Cooperation), placing them in the small to medium range (Cohen, 1988). Statistically significant sex differences were also found in that male students perceived significantly greater Enjoyment of Science Lessons as compared to their female counterparts with an effect size of -0.29 standard deviations. Comparing effect sizes between Tables 4.4 and 4.5, it can be seen that the magnitudes of differences were much larger for actual–preferred differences than for sex differences.

Simple correlation and multiple regression analyses were conducted to determine the strength of associations between the five scales of the SLEAQ (Involvement, Investigation, Cooperation, Student Negotiation and Connection) and the two scales of TOSRA (Attitude to Inquiry and Enjoyment of Science Lessons) and to answer the last research objective. There was a statistically significant correlation ($p<0.01$) between Attitude to Inquiry and each of the five learning environment scales, with correlations ranging from 0.29 (Student Negotiation) to 0.45 (Involvement). The correlation between Enjoyment of Science Lessons and the five learning environment scales were also statistically significant and ranged from 0.25 (Cooperation) to 0.53 (Connection).

A multiple regression analysis for each of the two attitude scales from TOSRA involved the association between students' attitudes and their perceptions of the whole set of the five learning environment scales. A significant multiple correlation ($p<0.01$) was found between each attitude scale and the set of learning environment scales in the SLEAQ. An inspection of the regression coefficients suggests that, Connection was positively and significantly related to Attitude to Inquiry, whereas Involvement, Cooperation and Connection were positively and significantly related to Enjoyment of Science Lessons. Overall, the present findings of positive associations between students' attitudes and their perceptions of their classroom learning environment replicate considerable prior research in a range of countries, as reviewed by Fraser (2012).

The following chapter provides a discussion of the findings as well as information regarding the significance and limitations of the study. It also highlights certain issues pertinent to attempts to replicate or extend this research in the future.

Chapter 5

SUMMARY AND CONCLUSION

5.1 Introduction

This final chapter presents conclusions and implications from my research. Also, I discuss the limitations of both the study and the methods used and propose research possibilities for the future.

My concluding discussion is presented under the following headings:

- Overview of the Thesis (Section 5.2)
- Major Findings of the Study (Section 5.3)
  - Research Question 1 (Section 5.3.1)
  - Research Question 2 (Section 5.3.2)
  - Research Question 3 (Section 5.3.3)
  - Research Question 4 (Section 5.3.4)
- Contributions of the Study (Section 5.4)
- Limitations of the Study (Section 5.5)
- Suggestions for Future Research (Section 5.6)
- Summary and Concluding Remarks (Section 5.7).

5.2 Overview of the Thesis

This thesis is divided into five chapters. Chapter 1 provided background to the study, including the following research questions:

- Is a science learning environment and attitude questionnaire valid when used with primary science students in Singapore?
- Are there differences between students' perceptions of actual and preferred learning environments?
- Are perceptions of the learning environment and attitudes different for students of different sexes?

- Is there a relationship between students' perceptions of the learning environment and their attitudes?

Chapter 1 also gave a brief description of the primary science education scene in Singapore. It provided the theoretical framework and discussed the learning environment and attitude instruments that were relevant and from which scales were selected for use in this study, namely, the What Is Happening In this Class? (WIHIC), the Constructivist Learning Environment Survey (CLES) and the Test of Science-Related Attitudes (TOSRA). The significance of this study was identified before concluding with an overview of the organisation of the various chapters in the thesis.

Chapter 2 reviewed literature related to this study. It provided insights into the historical background and development of research in the field of learning environments. It reviewed a wide range of learning environment instruments, as well as the types of research that have been undertaken using these learning environment questionnaires. In particular, it focused on two instruments, the CLES and WIHIC, as scales for this study were chosen from these instruments. Finally, it provided a comprehensive overview of literature related to the assessment of students' attitudes.

Chapter 3 provided information about the research approach used in the study, which was basically a quantitative one using a questionnaire survey involving students' perceptions and attitudes. This chapter also included descriptions of the instruments from which scales were selected for use in my study: the WIHIC (Involvement, Investigation and Cooperation), the CLES (Student Negotiation) and the TOSRA (Attitude to Scientific Inquiry and Enjoyment of Science Lessons). A scale, Connection, was also developed and included in the learning environment section of the questionnaire for this study to assess the extent to which students are able to make connections between what they have learned in science and their daily experiences. These conceptually-distinct learning environment and attitude scales formed the single instrument used in the study – Science Learning Environment and Attitude Questionnaire (SLEAQ) – to provide a single set of directions and response alternatives and therefore reduce administration time, fatigue and possible confusion among students.

In addition to justifying the choice of the questionnaire scales, Chapter 3 provided a description of the choice of schools and grade levels. The sample for this study involved 485 students from 16 different mainstream science classes in 4 different co-educational schools in Singapore. Information was also provided about the pilot testing and administration of the SLEAQ. This was followed by a discussion of the procedures for the collection of data and the methods of data analysis used to address each of the specific research questions.

Chapter 4 reported the results of the statistical analyses of questionnaire data that were undertaken to answer the research questions. The first set of analyses addressed the validity and reliability of the scales used in the SLEAQ. The next set of analyses addressed the second research question involving differences in students' perceptions of their actual and preferred learning environments. To address the third research question, results were reported for sex differences for each learning environment and attitude scale. The last set of results, which addressed the fourth research question, involved associations between students' attitudes and the learning environment. The results from Chapter 4 are summarised in greater detail in Section 5.3 of this chapter.

Chapter 5 concludes the thesis by providing an overview of this entire study. It provides background to the study and a brief summary of the highlights of each chapter. Major findings of the study are summarised followed by a discussion of the contributions of the study to the field of learning environments and to the teaching and learning of primary science in Singapore. This chapter concludes with the study's limitations and proposes recommendations for future research.

5.3 Major Findings of the Study

5.3.1 Research Question 1

The research instrument, SLEAQ, is made up of two parts, with one section focusing on a newly-developed scale for this study (Connection) together with scales from the CLES and WIHIC for assessing the science learning environment and the other section describing scales from TOSRA (with slight modifications) for assessing attitudinal outcomes. The SLEAQ was administered to 485 students and they were given 30 minutes to complete it. Separate statistical analyses of learning environment and attitude data were then undertaken to check factor structure, internal consistency reliability and ability to differentiate between classes.

Principal axis factoring with varimax rotation and Kaiser normalisation confirmed the structure of the 32-item five-scale version of the learning environment scales in the SLEAQ for the whole sample of 485 students using the individual student as the unit of analysis. A separate analysis was conducted for the actual and preferred versions. Six items (Involvement 3, Involvement 6, Involvement 7, Investigation 2, Investigation 4 and Student Negotiation 1) were eliminated based on the criteria that any item must have a factor loading of at least 0.40 on its own scale and less than 0.40 on all other scales.

Factor analysis of data for the learning environment scales from the SLEAQ revealed that the percentage of variance for the actual version of the different learning environment scales ranged between 3.90% and 33.99% and for the preferred version ranged between 3.39% and 38.37%. The total percentage variance was 55.94% and 58.72% for the actual and preferred versions, respectively. Eigenvalues ranged between 1.28 and 11.21 for the actual version and from 1.12 and 12.87 for the preferred version for different scales.

A similar principal axis factor analysis with varimax rotation and Kaiser normalisation was used to check the structure of the two attitude scales, Attitude to Inquiry and Enjoyment of Science Lessons, using the individual student as the unit of analysis. The same criteria for the retention of any item were used: it must have a factor loading of at least 0.40 on its own scale and less than 0.40 on all other scales. Based on the factor analysis, all items in the two scales were retained. The percentage of variance was 25.09% (Attitude to Inquiry) and 45.92% (Enjoyment of Science Lessons) with the total variance accounted being 71.01%. The eigenvalues were 3.01 for Attitude to Inquiry and 5.51 for Enjoyment of Science Lessons.

The factor analyses indicated strong support for the factorial validity of the 32-item five-scale structure of the actual and preferred learning environment scales and the two-scale structure of the attitude scales in the SLEAQ when used with primary science students in Singapore.

Analysis of the data also indicated sound internal consistency reliabilities for the learning environment and attitude scales using Cronbach's alpha coefficient for two units of analysis (the individual and the class mean), with alpha reliability coefficients ranging from 0.71 to 0.89 using the individual as the unit of analysis and from 0.86 to 0.98 using the class mean as the unit of analysis for the learning environment scales in the actual version of the SLEAQ. The alpha reliability coefficients ranged from 0.78 to 0.89 using the individual as the unit of analysis and from 0.90 to 0.97 using the class mean as the unit of analysis for the learning environment scales in the preferred version of the SLEAQ. For the student attitude scales of the SLEAQ, the alpha reliability coefficients were 0.88 (Attitude to Inquiry) and 0.95 (Enjoyment of Science Lessons) using the individual as the unit of analysis, and were 0.91 (Attitude to Inquiry) and 0.99 (Enjoyment of Science Lessons) with the class as the unit of analysis.

Finally, an analysis of variance (ANOVA) with class membership as the independent variable was used to determine the ability of each scale in the actual form of SLEAQ to differentiate between the perceptions of students in the different classes. The eta^2 statistics ranged from 0.15 to 0.21 for the different learning environment scales of the SLEAQ, and all five learning environment scales were able to differentiate significantly ($p<0.01$) between the 16 science classrooms.

Overall, these findings replicated previous validity results in various countries for WIHIC scales (Aldridge, Fraser & Huang, 1999; Chionh & Fraser, 2009; Kim, Fisher & Fraser, 2000; Wahyudi & Treagust, 2004), CLES scales (Aldridge, Fraser & Sebela, 2004; Aldridge, Fraser, Taylor & Chen, 2000; Nix, Fraser & Ledbetter, 2005) and TOSRA scales (Fraser, Aldridge & Adolphe, 2010; Martin-Dunlop & Fraser, 2008; Wong & Fraser, 1996).

5.3.2 Research Question 2

The second research question involved differences between students' perceptions of their actual and preferred classroom environments. To investigate this research question, students' responses to the actual and preferred versions of the learning environment scales in the SLEAQ were compared using a one-way MANOVA with repeated measures and using the individual students as the unit of analysis. Because the multivariate test using the Wilks' lambda criterion yielded statistically significant differences for the set of five learning environment scales as a whole, the univariate ANOVA results were interpreted separately for each individual learning environment scale.

Data analysis revealed that actual–preferred differences were statistically significant different ($p<0.001$) for each learning environment scale in the SLEAQ. The effect size for actual–preferred differences for different learning environment scales ranged from 0.81 to 1.07 standard deviations, placing them in the large magnitude range (Cohen, 1998).

The average item means for all the learning environment scales in the SLEAQ exceeded the value of 2.5, indicating that students perceived the activities to occur on average with a frequency between 'sometimes' to 'often'. The level of each learning environment dimension perceived to be actually present was lower for every scale, with the highest average item mean being 3.96 for actual Connection and the lowest average item mean being 2.91 for actual Investigation. Although it can be seen that students generally had positive perceptions of their science classrooms, they would prefer the learning environment to be even more positive across all dimensions, with students preferring activities associated with the learning environment items in SLEAQ to occur 'often' for Cooperation, Student Negotiation and Connection scales. Also students preferred the activities encompassed by the Involvement and Investigation scales to occur approximately 'sometimes' (average item mean of 3).

5.3.3 Research Question 3

The third research question focused on differences and similarities between male and female students' perceptions of the learning environment and their attitudes towards their science classes. Sex differences in classroom environment perceptions and attitudes were investigated using a one-way MANOVA with the student as the unit of analysis. Sex was the independent variable and the actual learning environment scales, the preferred learning environment scales and the attitude scales formed the set of dependent variables. Because the multivariate test using Wilks' lambda was statistically significant, the univariate ANOVA results were interpreted for each dependent variable.

Relative to females, male students perceived significantly ($p<0.01$) more actual Involvement and significantly less actual Cooperation and preferred significantly less Cooperation. The effect sizes for sex differences for these scales were -0.33 standard deviations (actual Involvement), 0.37 (actual Cooperation) and 0.36 (preferred Cooperation), suggesting a relatively small difference between the sexes (using Cohen's criteria) for the learning environment scales of Involvement and Cooperation.

Results for sex differences in student attitudes revealed that male and female students had similar Attitude to Inquiry scores and that sex differences were statistically non-significant. However, male students reported significantly ($p<0.01$) greater Enjoyment of their Science Lessons as compared to their female counterparts.

5.3.4 Research Question 4

The fourth research aim focused on associations between students' attitudes and the learning environment of primary science classrooms. The results of a simple correlation analysis revealed that each learning environment scale was significantly ($p<0.01$) and positively correlated with both Attitude to Inquiry and Enjoyment of Science Lessons. The correlations for Attitude to Inquiry ranged from 0.29 (Student Negotiation) to 0.45 (Involvement). For Enjoyment of Science Lessons, the correlations ranged from 0.25 (Cooperation) to 0.53 (Connection). The results suggest that improved student attitudes are associated with more emphasis on all of the aspects of the learning environment scales assessed in the SLEAQ.

The multiple correlation (R) for the set of learning environment scales was 0.39 for Attitude to Inquiry and 0.57 for Enjoyment of Science Lessons, and was statistically significant ($p<0.01$) in each case.

To identify which learning environment scales contributed most to the variance in student attitudes, the standardised regression coefficient (β) for each scale was examined. Connection was a significant independent predictor to Attitude to Inquiry, whereas Involvement, Cooperation and Connection were significant independent predictors of Enjoyment of Science Lessons. These results suggest that the more Connection there is in a science classroom, the more likely it is that learners have a positive Attitude to Inquiry. Students also seem to have greater Enjoyment of Science Lessons if there is more Involvement, Cooperation and Connection.

Overall, the simple correlation and multiple regression analyses suggest that student attitudes were consistently more positive in classes perceived to have higher learning environment scores. This replicates past studies, reviewed by Fraser (2012), that generally indicate consistent associations between student attitudes and dimensions of the classroom environment.

5.4 Contributions of the Study

The present research is distinctive as it is the first study into the classroom learning environments of students in mainstream primary science classrooms in Singapore. Previous studies of science learning environments in Singapore are limited in number (Quek, Wong & Fraser, 2005; Wong & Fraser, 1996) and were conducted with secondary students. Recently, Peer and Fraser (in press) investigated gender, grade-level and stream differences in the attitudes and learning perceptions of gifted primary science students.

My study is important because it has provided evidence for the validity and reliability of the SLEAQ (a combination of scales from CLES, WIHIC and TOSRA) when used specifically with mainstream primary science classes in Singapore. This questionnaire is quite versatile and is likely to be useful to other researchers and teachers in Singapore for a wide variety of applications in different contexts.

A comparison of students' perceptions of actual and preferred learning environments revealed that the magnitude of differences was large for most scales, which is consistent with previous studies conducted by Fraser (1998a), Fisher and Fraser (1983a) and Henderson, Fisher and Fraser (2000) that reported that students preferred a classroom environment that was more favourable than the one which they perceived as actually being present. This finding has important practical implications for teachers of primary science. As the results of the analysis of the SLEAQ data suggest that there is still room for improving the teaching of science as inquiry in the classroom in schools in Singapore, there is a need to reflect on ways to bridge the gap between the preferred and actual levels of the science classroom learning environment, beginning with the scale which is of the greatest legitimate cause of concern – Investigation. This might entail training teachers to improve their teaching strategies, which include the use of more investigation to better engage students. Having teachers' awareness raised is the first step in making these changes in the classroom. This research sought to provide insights for the science teachers in terms of students' perceptions, targeting awareness as the first step in making desirable pedagogical adjustments.

The final important contribution of this study has to do with the relatively strong, consistent and positive associations found between the science attitude scales and classroom environment scales. This is a reminder to educators of how student attitudes to science can be enhanced by creating positive classroom learning environments.

5.5 Limitations of the Study

In the interpretation of the findings of my study, several factors have to be considered. Firstly, as the sample came from co-educational schools, the findings thus are confined only to this context and should not be generalised to partially autonomous schools or to single-sex schools.

The sample size of 485 students was also relatively small, thus limiting the generalisability of the findings of the study. Given the constraints of time and resources (the research was carried out alongside teaching duties and commitments), the availability of students as research participants was entirely dependent on the limited network of friends who hold positions of authority in schools. Because participation also was subject to the consent of parents, the researcher had to make do with this pool of respondents. A concerted effort at the national level would be likely to yield findings that are more representative of the population.

Another limitation of this study was its dependence on quantitative data. While the instruments from which scales were selected have been validated and found to be reliable, a more complete picture might have been obtained through triangulation of the quantitative data with a variety of qualitative data in other learning environment studies (Tobin & Fraser, 1998).

A third limitation possibly could be that modifying the research instruments might have led to the loss of validity. The original intent of the selected instruments (CLES, WIHIC and TOSRA) was for use predominantly in secondary-level classes. As the present research was undertaken in primary science classes, parts of these questionnaires had been modified and adapted for use in that context. This could have resulted in concepts not carrying over from one educational level to the other.

The timing of the administration of the questionnaire was potentially a problem. Because the questionnaire was administered at the end of the year after the examinations, students might have had a clearer memory of science lessons just before the examinations when the teacher would have been rushing for curriculum time to revise and would have provided less hands-on activities. This could have affected the way in which students answered the questionnaire and thus the mean scores obtained for some scales such as Investigation.

In many similar studies, researcher bias in interpreting the results has been a possibility and could be one of the limitations of this study. Although care was taken to be objective in the analysis and interpretation of the data, it is possible that some preconceived notions could have affected the interpretation of the data and the ways in which the findings were reported.

5.6 Suggestions for Future Research

My study provided considerable useful evidence to support the validity of SLEAQ scales based on exploratory factor analysis and analysis for internal consistency reliability and ability to differentiate between classrooms (see Section 4.2). In future research, further support for the validity of the SLEAQ could be obtained by also conducting confirmatory factor analysis following the lead of Dorman's (2003, 2008) analyses of data for the WIHIC described in Section 2.5.

Because the SLEAQ was found to be a valid and reliable instrument when used in the primary science classrooms in Singapore, it could be used to assess the learning environment at different grade levels at the primary-school level in future research. This information could be useful for determining if sex differences in SLEAQ scale scores vary with grade level and, if so, the extent of these variations.

Because my study focused on students' perceptions of classroom environment in co-educational schools, it could be illuminating in future studies to compare single-sex schools with co-educational schools in terms of students' perceptions of classroom learning environment.

The relatively small size sample in this study revealed some insights into the learning environment in Singaporean primary science classrooms. But it would be worthwhile to involve larger samples in future studies. This study could also be extended further to involve a cross-national sample across Asian countries, so as to increase the generalisability of the findings.

Future studies could include investigating other domains of student outcomes, such as student achievement in particular, in order to provide a more complete picture of the relationship between the learning environment and student outcomes.

In addition to making use of the SLEAQ to glean insights from students, it would also be desirable in future research to use the SLEAQ to investigate teachers' perceptions of the learning environment. Also, it could be interesting to consider both teachers' and students' perceptions and to investigate differences in their perceptions of the learning environments of the same classrooms.

Furthermore, future studies should include a qualitative component involving interviews and other qualitative data-collection techniques as suggested by Tobin and Fraser (1998). Qualitative methods could serve as checks on the validity of the questionnaire responses and help in explaining relationships. The use of both qualitative and quantitative methods together could further enrich the insights gleaned from either method alone.

5.7 Summary and Concluding Remarks

This study involved 485 students from 16 Singaporean mainstream primary science classes (across 4 schools) provided answers to the four research questions listed in Section 5.2:

- The SLEAQ (a combination of scales from the CLES, WIHIC and TOSRA with slight modifications) was valid and reliable when used in Singaporean mainstream primary science classrooms. The findings replicate previous research which incorporated the use of these instruments (Chionh & Fraser, 2009; Wong & Fraser, 1996).

- Students generally have positive perceptions of their science classrooms, but they would prefer the learning environment to be more positive across all dimensions, especially Investigation. These findings are consistent with previous studies (Fraser, 1998a; Fisher & Fraser, 1983a; Henderson, Fisher & Fraser, 2000).

- Male students perceived significantly more actual Involvement and less actual Cooperation and preferred significantly less Cooperation. Male and female students had similar Attitude to Inquiry scores, but male students had greater Enjoyment of Science Lessons scores.

- Positive associations were found between Attitude to Inquiry and Enjoyment of Science Lessons and students' perceptions of the science classroom. In particular, Connection was a significant independent predictor to Attitude to Inquiry, whereas Involvement, Cooperation and Connection were significant independent predictors of Enjoyment of Science Lessons. These results suggest that the more Connection there is in a science classroom, the more likely it is that learners would have a positive Attitude to Inquiry. Students would also have greater Enjoyment of their Science Lessons if there is more Involvement, Cooperation and Connection. This replicates the findings of past studies reviewed by Fraser (2012).

The present study is one of many in the growing field of learning environment research. Though there were limitations to the study, I was able to provide educational researchers with further evidence of the validity and reliability of scales for assessing the classroom environment and attitudes. It is hoped that this study will be a small contribution to the limited amount of research undertaken into science learning environments in Singapore (Peer & Fraser; in press; Quek, Wong & Fraser, 2005; Wong & Fraser, 1996) and will provide a more accurate picture of the state of science teaching and learning environments in the local Singapore context.

REFERENCES

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

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

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* (Advances in Learning Environments Research series). Rotterdam, the Netherlands: Sense Publishers.

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., Laugksch, R. C., Seopa, M. A., & Fraser, B. J. (2006). Development and validation of an instrument to monitor the implementation of outcomes-based learning environments in science classrooms in South Africa. *International Journal of Science Education, 28*, 45–70.

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.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. Washington, DC: National Academy Press.

Barnette, J. (2000). Effects of stem and Likert response option reversals on survey internal consistency: If you feel the need, there is a better alternative to using those negatively worded stems. *Educational and Psychological Measurement, 60*, 361–370.

Brophy, J., & Good, T. L. (1986). Teacher behavior and student achievement. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 328–375). New York: Macmillan.

Brophy, J., & Putnam, J. G. (1979). Classroom management in the elementary grades. In D. Duke (Ed.), *Classroom management* (Seventy-eighth Yearbook of the National Society for the Study of Education, Part 2) (pp. 41–47). Chicago, IL: University of Chicago Press.

Bull, E. K. (2001). *Factors which determine the continuation of science education for eighth-grade students.* Unpublished doctoral thesis, Curtin University of Technology, Perth, Western Australia.

Cheung, D. (2009). Students' attitudes toward chemistry lessons: The interaction effect between grade level and gender. *Research in Science Education, 39*, 75–91.

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 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 Earlbaum Associates.

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

Curriculum Planning & Development Division Ministry of Education. (2007). *2008 Syllabus Science Primary Standard/Foundation*. Singapore: Ministry of Education.

DeBoer, G. E. (1991). *A history of ideas in science education: Implications for practice.* New York: Teachers College Press.

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

den Brok, P., Fisher, D., & Scott, R. (2005). The importance of teacher interpersonal behaviour for student attitudes in Brunei primary science classes. *International Journal of Science Education, 27*, 765−779.

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? (WIHIC) questionnaire. *Learning Environments Research*, *11*, 179–197.

Dryden, M. & Fraser, B. J. (1996, April). *Evaluating urban systematic reform using classroom learning environment instruments.* Paper presented at the annual meeting of the American Educational Research Association, New York.

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*, 146−156.

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

Fisher, D. L., & Fraser, B. J. (1983b, April). *Use of Classroom Environment Scale in investigating effects of psychosocial milieu on science students' outcomes*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Dallas. TX.

Fisher, D. L., Fraser, B. J., & Rickards, T. W. (1997, April). *Gender and cultural differences in teacher−student interpersonal behaviour.* Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

Fisher, D. L., Goh, S. C., Wong, A. F. L., & Rickards, T. W. (1997). Perceptions of interpersonal teacher behavior in secondary science classroom in Singapore and Australia. *Journal of Applied Research in Education, 1*, 2−13.

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 & student outcomes in senior high school biology. *American Biology Teacher, 59,* 214-219.

Fisher, D. L., & Khine, M. S. (Eds.). (2006). *Contemporary approaches to research on learning environments: Worldviews*. Singapore: World Scientific.

Fraser, B. J. (1977a). Attitude to the social implications of science: Its measurement and correlates. *Australian Science Teachers Journal, 23*, 96–99.

Fraser, B. J. (1977b). Selection and validation of attitude scales for curriculum evaluation. *Science Education, 61*, 317–329.

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

Fraser, B. J. (1979). *Test of Enquiry Skills (TOES).* Melbourne, Australia: Australian Council for Educational Research.

Fraser, B. J. (1981). *Test of Science-Related Attitudes handbook* (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 and H. J. Walberg (Eds.), *Educational environments: Evaluation, antecedents and consequences* (pp. 3-27). London: Pergamon Press.

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

Fraser, B. J. (1998a). The birth of a new journal: Editor's introduction. *Learning Environments Research, 1*, 1–5.

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

Fraser, B. J. (1998c). 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. (2001). Twenty thousand hours. *Learning Environments Research, 4*, 1–5.

Fraser, B. J. (2002). Learning environments research: Yesterday, today and tomorrow. In S. C. Goh & M. S. Khine (Eds.), *Studies in educational learning environments: An international perspective* (pp. 1–25). Singapore: World Scientific Publishing.

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

Fraser, B. J. (2012). Classroom learning environments: Retrospect, context and prospect. In B. J. Fraser, K. G. Tobin & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 1191-1232). New York: Springer.

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, W. (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., & Fisher, D. L. (1982a). Effects of classroom psychosocial environment on student learning. *British Journal of Educational Psychology, 52*, 374–377.

Fraser, B. J., & Fisher, D. L. (1982b). Predictive validity of My Class Inventory. *Studies in Educational Evaluation, 8*, 129–140.

Fraser, B. J., & Fisher, D. L. (1982c). Predicting students' outcomes from their perceptions of classroom psychosocial environment. *American Educational Research Journal, 19*, 498–518.

Fraser, B. J., & Fisher, D. L. (1983a). 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., & McRobbie, C. J. (1996, April). *Development, validation, and use of personal and class forms of a new classroom environment instrument.* Paper 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., & 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: A cross-national study. *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., & Treagust, D. F. (1986). Validity and use of an instrument for assessing classroom psychosocial environment in higher education. *Higher Education*, *15*, 37–57.

Fraser, B. J., Treagust, D. F., & Dennis, N. C. (1986). Development of an instrument for assessing classroom psychosocial environment at universities and colleges. *Studies in Higher Education*, *11*, 43–54.

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

Fraser, B. J., Williamson, J. C., & Tobin, K. (1987). Use of classroom and school climate scales in evaluating alternative high schools. *Teaching and Teacher Education, 3*, 219-231.

Gardner, P., & Gauld, C. (1990). Labwork and students' attitude. In E. H. Hazel (Ed.), *The student laboratory and the science curriculum* (pp. 132−156). London, England: Routledge.

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., & Fraser, B. J. (2000). Teacher interpersonal behaviour and elementary students' outcomes. *Journal of Research in Childhood Education, 14*, 216−231.

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

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

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

Henderson, D., Fisher, D. L., & Fraser, B. J. (1995). *Gender differences in biology students' perceptions of actual and preferred learning environments.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Francisco.

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

Hodson, D. (1988). Experiments in science and science teaching: *Educational Philosophy and Theory*, *20*(2), 53−66.

Hofstein, A., Cohen, I., & Lazarowitz, R. (1996). The learning environment of high school students in chemistry and biology laboratories. *Research in Science & Technological Education, 14*, 103−115.

Khine, M. S., & Fisher, D. L. (Eds.). (2003). *Technology-rich learning environments: A future perspective*. Singapore: World Scientific.

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 science classes in Korea. *Evaluation and Research in Education*, *14*, 3–22.

Klopfer, L. E. (1971). Evaluation of learning in science. In B. S. Bloom, J. T. Hastings & G. F. Madaus (Eds.), *Handbook of formative and summative evaluation of student learning* (pp. 559–641). New York: McGraw-Hill.

Koballa, T. R. (1988). Attitude and related concepts in science education. *Science Education, 72*, 115−126.

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

Lee, S., & Fraser, B. J. (2001, April). *High school science classroom learning environments in Korea.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, St. Louis, MO.

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.

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology, 140*, 44–53.

Liu, L., & Fraser, B. J. (2013). Development and validation of an English classroom learning environment inventory and its application in China. In M. S. Khine (Ed.), *Application of structural equation modelling in educational research and practice* (pp. 75–89). Sense Publishers.

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.

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.

Margianti, E. S., Fraser, B. J., & Aldridge, J. M. (2001a, April). *Classroom environment and students' outcomes among university computing students in Indonesia*. Paper presented at the annual meeting of the American Educational Research Association, Seattle, WA.

Margianti, E. S., Fraser, B. J., & Aldridge, J. M. (2001b, December). *Investigating the learning environment and students' outcomes in university level computing courses in Indonesia*. Paper presented at the annual conference of the Australian Association for Research in Education, Fremantle, Australia.

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.

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

Ministry of Education (2013). *Compulsory education*. Retrieved from *http://www.moe.gov.sg/initiatives/compulsory-education/* November 2013.

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

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

Moos, R. H., & Moos, B. S. (1978). Classroom social climate and student absences and grades. *Journal of Educational Psychology, 70*, 263–269.

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

Moos, R. H., & Trickett, E. J. (1987). *Classroom Environment Scale manual* (2nd ed.). Palo Alto, CA: Consulting Psychologists Press.

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

National Research Council. (1996). *National Science Education Standards.* Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning.* Washington, DC: National Academy Press.

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.

Nunnally, J. C. (1978). *Psychometric theory* (2nd ed.). New York: McGraw-Hill.

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

Parker, L., & Rennie, L. (2002). Teachers' implementation of gender-inclusive instructional strategies in single-sex and mixed-sex science classrooms. *International Journal of Science Education, 24*, 881–897.

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

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.

Pickett, L. H., & Fraser, B. J. (2009). Evaluation of a mentoring program 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. 1–15). New York: Nova Science Publishers.

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.

Raaflaub, C., & Fraser, B. J. (2013). Subject and sex differences in the learning environment − Perceptions and attitudes of Canadian Mathematics and Science students using laptop computers. *Curriculum and Teaching, 28*, 57−78.

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

Riah, H., Fraser, B. J., & Rickards, T. (1997). *Interpersonal teacher behaviour in chemistry classes in Brunei Darussalam's secondary schools.* Paper presented at the International Seminar on Innovations in Science and Mathematics Curricula, Bandar Seri Begawan, Brunei Darussalam.

Rickards, A. W. (1998). *The relationship of teacher–student interpersonal behaviour with student sex, cultural background and student outcomes.* Unpublished doctoral thesis, Curtin University of Technology, Perth, Western Australia.

Robinson, E., & Fraser, B. J. (2013). Kindergarten students' and parents' perceptions of science classroom environments: Achievement and attitudes. *Learning Environments Research, 16*, 1–17.

Roth, W.-M. (1998). Teacher-as-researcher reform: Student achievement and perceptions of learning environment. *Learning Environments Research, 1*, 75–93.

Scantlebury, K. (2012). Still part of the conversation: Gender issues in science education. In B. J. Fraser, K. G. Tobin & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 499–512). New York: Springer.

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

Schwab, J. J. (1962). The teaching of science as enquiry. In J.J. Schwab & P.F. Brandwein (Eds.), *The teaching of science* (pp. 3-103). Cambridge, MA: Harvard University Press.

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.

Shrigley, R. L., Koballa, T. R., & Simpson, R. D. (1988). Defining attitude for science educators. *Journal of Research in Science Teaching, 25*, 659–678.

Shulman, L. S., & Tamir, P. (1972). Research on teaching in the natural sciences. In R. M. W. Travers (Ed.), *Second handbook of research on teaching* (pp. 1098–1148). Chicago: Rand McNally.

Spinner, H., & Fraser, B. J. (2005). Evaluation of an innovative mathematics program in terms of classroom environment, student attitudes, and conceptual development. *International Journal of Science and Mathematics Education*, *3*, 267–293.

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.

Taylor, P. C., Dawson, V., & Fraser, B. J. (1995, April). *Classroom learning environments under transformation: A constructivist perspective.* Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Taylor, P. C., & Fraser, B. J. (1991, April). *Development of an instrument for assessing constructivist learning environments.* Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

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

Taylor, P. C., Fraser, B. J., & White, L. R. (1994, April). *The revised CLES: A questionnaire for educators interested in the constructivist reform of school science and mathematics.* Paper presented at the annual meeting of the American Educational Research Association, Atlanta, GA.

Teh, G., & Fraser, B. J. (1994). An evaluation of computer-assisted learning in terms of achievement, attitudes and classroom environment. *Evaluation and Research in Education, 8*, 147–161.

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

Thompson, B. (1998a). Review of 'What if there were no significant tests?' *Educational and Psychological Measurement, 58*, 334–346.

Thompson, B. (1998b, April). *Five methodology errors in educational research: The pantheon of statistical significance and other faux pas*. Invited address presented at the annual meeting of the American Educational Research Association, San Diego, CA.

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

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

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. (Ed.). (1979). *Educational environments and effects: Evaluation, policy, and productivity*. Berkeley, CA: McCutchan.

Walberg, H. J. (1981). A psychological theory of educational productivity. In F. Farley & N. J. Gordon (Eds.), *Psychology and education: The state of the union* (pp. 81–108). Berkeley, CA: McCutchan.

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

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

Wilks. D. R. (2000). *An evaluation of classroom learning environments using critical constructivist perspectives as a referent for reform.* Unpublished doctoral thesis, Curtin University of Technology, Perth, Australia.

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.

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

Wubbels, Th., Brekelmans, M., & 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, Th., & Brekelmans, M. (2005). Two decades of research on teacher student relationships in class. *International Journal of Educational Research, 43*, 6–24.

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

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.

APPENDICES

Appendix A

Science Learning Environment and Attitude Questionnaire (Primary)

Directions
This questionnaire has a total of 50 statements.

Each statement is meant to describe what your actual classroom is like and what you hope your preferred classroom would be.

Some statements are fairly similar to other statements. Do not worry about this. Simply give your opinion for all statements.

Practice Example:
Suppose you were given a statement: "I discuss ideas in class."

If you think you Some-times discuss ideas in the actual classroom, you would circle number 3 on your Answer Sheet.

However, if you think you like to see this practice of discussing ideas in your preferred classroom Often, you would circle 4 on your Answer Sheet.

		ACTUAL CLASSROOM (What this class is actually like)					PREFERRED CLASSROOM (What you would prefer this classroom to be like)				
Involvement		Almost Never	Seldom	Some-times	Often	Almost Always	Almost Never	Seldom	Some-times	Often	Almost Always
1	I discuss ideas in class.	1	2	(3)	4	5	1	2	3	(4)	5

There are no 'right' or 'wrong' answers. **Be sure to give an answer for all questions.** If you change your mind about an answer, just cross it out and circle another.

School	
Name	
Index No.	
Gender	Male / Female (Please delete where applicable)

		ACTUAL CLASSROOM (What this class is actually like)					PREFERRED CLASSROOM (What you would prefer this classroom to be like)				
Involvement		Almost Never	Seldom	Some-times	Often	Almost Always	Almost Never	Seldom	Some-times	Often	Almost Always
1	I discuss ideas in class.	1	2	3	4	5	1	2	3	4	5
2	I give my opinions during class discussions.	1	2	3	4	5	1	2	3	4	5
3	My teacher asks me questions.	1	2	3	4	5	1	2	3	4	5
4	My ideas and suggestions are used during classroom discussions.	1	2	3	4	5	1	2	3	4	5
5	I ask my teacher questions.	1	2	3	4	5	1	2	3	4	5
6	I explain my ideas to other students.	1	2	3	4	5	1	2	3	4	5
7	Students discuss with me how to go about solving problems.	1	2	3	4	5	1	2	3	4	5
8	I am asked to explain how I solve problems.	1	2	3	4	5	1	2	3	4	5

		ACTUAL CLASSROOM (What this class is actually like)					PREFERRED CLASSROOM (What you would prefer this classroom to be like)				
Investigation		Almost Never	Seldom	Some-times	Often	Almost Always	Almost Never	Seldom	Some-times	Often	Almost Always
9	I carry out investigations to test my ideas.	1	2	3	4	5	1	2	3	4	5
10	I am asked to think about the evidence for statements.	1	2	3	4	5	1	2	3	4	5
11	I carry out investigations to answer questions coming from discussions.	1	2	3	4	5	1	2	3	4	5
12	I explain the meaning of statements, diagrams and graphs.	1	2	3	4	5	1	2	3	4	5
13	I carry out investigations to answer questions which puzzle me.	1	2	3	4	5	1	2	3	4	5
14	I carry out investigations to answer my teacher's questions.	1	2	3	4	5	1	2	3	4	5
15	I find out answers to questions by doing investigations.	1	2	3	4	5	1	2	3	4	5
16	I solve problems by using information obtained from my own investigations.	1	2	3	4	5	1	2	3	4	5
Cooperation		Almost Never	Seldom	Some-times	Often	Almost Always	Almost Never	Seldom	Some-times	Often	Almost Always
17	I cooperate with other students when doing assignment work.	1	2	3	4	5	1	2	3	4	5
18	I share my books and resources with other students when doing assignments.	1	2	3	4	5	1	2	3	4	5
19	When I work in groups in this class, there is teamwork.	1	2	3	4	5	1	2	3	4	5
20	I work with other students on projects in this class.	1	2	3	4	5	1	2	3	4	5
21	I learn from other students in this class.	1	2	3	4	5	1	2	3	4	5
22	I work with other students in this class.	1	2	3	4	5	1	2	3	4	5
23	I cooperate with other students on class activities.	1	2	3	4	5	1	2	3	4	5
24	Students work with me to achieve class goals.	1	2	3	4	5	1	2	3	4	5

		ACTUAL CLASSROOM (What this class is actually like)					PREFERRED CLASSROOM (What you would prefer this classroom to be like)				
Student Negotiation		Almost Never	Seldom	Some-times	Often	Almost Always	Almost Never	Seldom	Some-times	Often	Almost Always
25	I get the chance to talk to other students.	1	2	3	4	5	1	2	3	4	5
26	I talk with other students about how to solve problems.	1	2	3	4	5	1	2	3	4	5
27	I explain my understanding to other students.	1	2	3	4	5	1	2	3	4	5
28	I ask other students to explain their thoughts.	1	2	3	4	5	1	2	3	4	5
29	Other students ask me to explain my ideas.	1	2	3	4	5	1	2	3	4	5
30	Other students explain their ideas to me.	1	2	3	4	5	1	2	3	4	5
Connection		Almost Never	Seldom	Some-times	Often	Almost Always	Almost Never	Seldom	Some-times	Often	Almost Always
31	I learn how science can be part of my life.	1	2	3	4	5	1	2	3	4	5
32	I learn how science helps me to understand the world better.	1	2	3	4	5	1	2	3	4	5
33	I can see that science plays a role in my life.	1	2	3	4	5	1	2	3	4	5
34	I can apply science to my everyday life.	1	2	3	4	5	1	2	3	4	5
35	I make use of information from resources around me to explain my findings.	1	2	3	4	5	1	2	3	4	5
36	I can make connections between my findings and scientific knowledge.	1	2	3	4	5	1	2	3	4	5
37	My teacher helps me to apply what I learn to the world around me.	1	2	3	4	5	1	2	3	4	5
38	My teacher directs me to information from resources to explain my findings.	1	2	3	4	5	1	2	3	4	5

Attitude to Scientific Inquiry		Almost Never	Seldom	Some-times	Often	Almost Always
39	I would prefer to find out why something happens by doing an experiment than by being told.	1	2	3	4	5
40	I would prefer to do experiments than to read about them.	1	2	3	4	5
41	I would prefer to do my own experiments than to find out information from a teacher.	1	2	3	4	5
42	I would rather solve a problem by doing an experiment than be told the answer.	1	2	3	4	5
43	I would prefer to do an experiment on a topic than to read about it in science magazines.	1	2	3	4	5
44	I would rather do an experiment to find out for myself than to agree with other people.	1	2	3	4	5
Enjoyment of Science Lessons		Almost Never	Seldom	Some-times	Often	Almost Always
45	Science lessons are fun.	1	2	3	4	5
46	School should have more Science lessons each week.	1	2	3	4	5
47	Science is one of the most interesting school subjects.	1	2	3	4	5
48	I really enjoy going to Science lessons.	1	2	3	4	5
49	I look forward to Science lessons.	1	2	3	4	5
50	I would enjoy school more if there were more Science lessons.	1	2	3	4	5

Appendix B

Curtin University of Technology

Curtin University of Technology
Science and Mathematics Education Centre

Participant Information Sheet for Student Participant

My name is Su Fen and I am currently completing a piece of research for my PhD (Doctor of Philosophy - Science and Mathematics Education) at Curtin University of Technology.

Purpose of Research
I am using a questionnaire to investigate the actual and preferred inquiry learning environments among primary science students in Singapore.

Your Role
I would need you to complete a questionnaire which will take approximately 30 minutes, which will be administered by me.

Consent to Participate
Your involvement in the research is entirely voluntary and you have the right to withdraw at any stage without it affecting your rights or my responsibilities. When you have signed the consent form I will assume that you have agreed to participate and allow me to use your data in this research.

Confidentiality
All information provided by you will be kept confidential and the name of school, teacher or student will not be included in any form in the published report.

Further Information
This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval number xxxxx). If you would like further information about the study, please feel free to contact me on my mobile at 9138 1976 or by email: gohsufen@gmail.com.

Alternatively, you can contact my supervisor Professor Barry Fraser at B.Fraser@curtin.edu.au.

I would like to thank you for your involvement in this research and your participant is greatly appreciated.

Curtin University of Technology

CONSENT FORM FOR STUDENT PARTICIPANTS

- I understand the purpose and the procedures of the study.
- I have been provided with the participant information sheet.
- I understand that my involvement in this study itself might not benefit me.
- I understand that my involvement is voluntary and I can withdraw from it any time without problem.
- I understand that no personal identifying information like my name or address will be used and that all information will be securely stored for 5 years before being destroyed.
- I have been given the opportunity to ask questions.
- I agree to participate in the study outlined to me.

Signature : ________________ Date: ________________

Witness Signature : ________________ Date: ________________

Curtin
University of Technology

Curtin University
Science and Mathematics Education Centre

Participant Information Sheet for Parents

My name is Su Fen and I am currently completing a piece of research for my PhD (Doctor of Philosophy) at Curtin University.

Purpose of Research
I am using a questionnaire to investigate the actual and preferred science learning environments among primary science students in Singapore.

Your Role
You would need to agree to allow your child to complete a questionnaire in class which will take approximately 30 minutes. This questionnaire will be administered by me.

Consent to Participate
Your involvement in the research is entirely voluntary and you have the right to withdraw your child at any stage without it affecting his/her rights or my responsibilities. When you have signed the consent form, I will assume that you have agreed to allow your child to participate and allow me to use the data in this research.

Confidentiality
All information provided by your child will be kept confidential. The name of the school, teacher or student will not be included in any form in the published report.

Further Information
This research has been reviewed and given approval by Curtin University Human Research Ethics Committee. If you would like further information about the study, please feel free to contact me on my mobile at 9138 1976 or by email: gohsufen@gmail.com.

Alternatively, you can contact my supervisor Professor Barry Fraser at B.Fraser@curtin.edu.au.

I would like to thank you for agreeing to allow your child to be involved in this research and his/her participation is greatly appreciated.

Curtin University of Technology

CONSENT FORM FOR PARENTS

- I understand the purpose and the procedures of the study.
- I have been provided with the participant information sheet.
- I understand that my child's involvement in this study itself might not benefit him/her.
- I understand that my child's involvement is voluntary and he/she can withdraw from it at any time without a problem.
- I understand that no personal identifying information like my child's name or address will be used and that all information will be securely stored for 5 years before being destroyed.
- I agree to allow my child to participate in the study outlined to me.

Signature : ________________ Date:________________

Witness Signature : ________________ Date:________________

Curtin University of Technology

Curtin University of Technology
Science and Mathematics Education Centre

Participant Information Sheet for Teacher Participant

My name is Su Fen and I am currently completing a piece of research for my PhD (Doctor of Philosophy - Science and Mathematics Education) at Curtin University of Technology.

Purpose of Research
I am using a questionnaire to investigate the actual and preferred inquiry learning environments among primary science students in Singapore.

Your Role
I would need you to provide me a time where I would be able to come into your classroom to administer the questionnaire to your students.

Consent to Participate
Your involvement in the research is entirely voluntary and you have the right to withdraw at any stage without it affecting your rights or my responsibilities. Your involvement in this research will not be used as an evaluation of you as a teacher. When you have signed the consent form I will assume that you have agreed to participate and allow me to use your data in this research.

Confidentiality
All information provided by you will be kept confidential and the name of school, teacher or student will not be included in any form in the published report.

Further Information
This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval number xxxxx). If you would like further information about the study, please feel free to contact me on my mobile at 9138 1976 or by email: gohsufen@gmail.com.

Alternatively, you can contact my supervisor Professor Barry Fraser at B.Fraser@curtin.edu.au.

I would like to thank you for your involvement in this research and your participant is greatly appreciated.

Curtin
University of Technology

CONSENT FORM FOR TEACHER PARTICPANTS

- I understand the purpose and the procedures of the study.
- I have been provided with the participant information sheet.
- I understand that my involvement in this study itself might not benefit me.
- I understand that my involvement is voluntary and I can withdraw from it any time without problem.
- I understand that no personal identifying information like my name or address will be used and that all information will be securely stored for 5 years before being destroyed.
- I have been given the opportunity to ask questions.
- I agree to participate in the study outlined to me.

Signature : ___________________ Date: __________________

Witness Signature : __________________ Date: __________________