Science and Mathematics Education Centre

Effectiveness of Teachers' Participation in a Mathematics Networked Learning Community in Terms of Students' Classroom Environments and Attitudes to Mathematics in Singapore

Cynthia Seto

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

December 2014

DECLARATION

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

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Cynthia Seto

Date: December 2014

Abstract

Networked Learning Community, a new initiative in teacher professional development in Singapore, aims to enhance teaching expertise and professionalism. The idea of networked learning community was largely based on theories and studies emanating from the Western literature but, so far, there has been no research undertaken in Singapore into the effectiveness of networked learning on teachers' instructional practice and student learning. Because every Singaporean student would have taken about 1600 hours of instruction in mathematics throughout their ten years of education, the perspectives of students can provide a valuable source of data for assessing the effectiveness of professional development.

To provide some evidence about the effectiveness of networked learning communities in Singapore, I used a learning environment framework to provide process criteria of effectiveness. Also, students' attitudes to mathematics were used as criteria of effectiveness. To assess students' perceptions of classroom learning environment and attitudes to mathematics, I developed and validated a new instrument called the Mathematics Classroom Environment and Attitude (MCEA) questionnaire. The MCEA questionnaire has a total of 40 items that assess the five scales of Cooperation, Teacher Support, Involvement, Problem Solving and Enjoyment.

The MCEA questionnaire was used in a pretest–posttest quasi-experimental design to compare the changes in classroom environment and attitudes of those classes whose teachers' participated in networked learning community (experimental group) with those classes whose teachers were not in the networked learning community (comparison group).

Data analyses supported the factor structure, internal consistency reliability and discriminant validity of the MCEA questionnaire when used during 2012 with 375 Primary 5 students from 10 mathematics classes in five schools in Singapore. ANOVA showed that each scale of the MCEA was able to differentiate between the perceptions of students in the different classes.

MANOVA with repeated measures and effect sizes were conducted separately for the experimental and comparison groups to ascertain the statistical significance and magnitude of pretest–posttest changes in the set of five learning environment and enjoyment scales as a whole. Overall, pretest–posttest changes were larger in magnitude for the experimental group (teachers who participated in networked learning) than for the comparison group (teachers who did not participate in networked learning) for every learning environment and attitude scale.

Simple correlation and multiple regression analyses revealed positive associations between the learning environment and students' attitudes towards mathematics. All of the four learning environment scales were statistically significantly correlated with attitudes to mathematics. Teacher support and problem solving were significant independent predictors of students' attitudes towards mathematics for both the pretest and posttest data.

A key practical implication from my study for educators is that teachers' participation in networked learning communities is likely to lead to positive learning environments in these teachers' classrooms. Another implication is that creating positive classroom environments is likely to promote positive student attitudes to mathematics.

Acknowledgements

I would like to express my deep gratitude to my supervisor, Professor Barry Fraser, Director, Science and Mathematics Education Centre, Curtin University, for his insightful critiques, patient guidance and excellent supervision of this research and preparation of this thesis. His prompt responses with invaluable feedback to my numerous emails and his words of encouragement were a source of inspiration to me. I have learnt much from him and I believe this rich experience will be a great springboard for future research in the area of learning environment.

My sincere thanks to Dr Rekha Koul, Research Fellow at Curtin, for providing me with advice and support during my data analysis. With her guidance, I was able to glean deeper insights into the data for my thesis. I am grateful to Professor David Treagust who showed great interest in my research findings during the AERA 2014 Conference and asked thought-provoking questions which deepened my understanding of this study.

During this journey, I was also privileged to know Su Fen and Donna who were always so willing to help me. I greatly appreciate their support in guiding me to navigate the OASIS Portal and sharing their experiences in preparing for my AERA poster presentation. It was great to know a fellow PhD student, Nancy, who went with me to Curtin University for a week. Besides the friendship, we had a great time in supporting each other in our study.

I would also want to extend my thanks to the principals, teachers and students of the schools in Singapore involved in my research project. This study would not have been possible without their support and cooperation.

Last but not least, I would like to dedicate this thesis to my wonderful family, my husband and daughter, who are the inspiration for everything I do. My immense gratitude goes to my husband who supported, encouraged and even endured with me throughout this journey. My daughter was a great help in technical matters. The completion of this thesis would not have been possible without their love and understanding.

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INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

To remain competitive in the knowledge-based economy, many countries, including Singapore, embarked on educational reforms to prepare their citizenry to meet the challenges of the future (Gopinathan, 2007). The success of any intended reform of education is highly dependent on the quality of teaching. The literature supports the contention that professional learning of teachers is essential in order to achieve the desired educational outcomes at the system level (Darling-Hammond & Lieberman, 2012). Learning and collaboration in networks beyond schools have been shown to be a major conduit for teachers to improve their practice (Cochran-Smith & Lytle, 1999; Lieberman & Grolnick, 1996, 1997).

In recent years, there has been a proliferation of learning communities for teachers on Singapore education landscape. In particular, the Academy of Singapore Teachers has actively encouraged the formation of networked learning communities to promote professional learning within the teaching fraternity. The motivation to adopt networked learning community at the system level is based on the belief that it will support school-based curriculum innovation, promote students' academic excellence, and achieve a more-even standard of professional excellence across schools.

As a researcher, I am interested in understanding the psychosocial learning environment that exists in our mathematics classrooms and the attitudes of students towards mathematics. Although networked learning communities have been introduced since 2010, no empirical study has been carried out in Singapore to investigate the outcomes of such forms of professional development. The only source of evaluation was a few periodic surveys based on teachers' self-reports or the administration of a satisfaction survey at the end of the session (which is a common mode of assessing teachers' learning in Singapore). Although teachers' satisfaction with their professional learning experience is desirable, more information is needed to infer how much teachers have learned, whether teachers are likely to change their instructional practices and whether student achievement is likely to be affected (Guskey, 1995; Wilson & Berne, 1999). I have been a Master Teacher for five years and one of my roles is to raise the professional standard of teaching in Primary Mathematics. Besides conducting workshops, part of my work is to engender the growth of networked learning communities in an attempt to promote teacher leadership and ownership of their professional development. So, at a more personal level, I would like to know the impact of networked learning communities on student outcomes.

The underlying objective of professional development is to help teachers to become more effective in their practice in order to enhance the learning of students. Whereas instructional practices need to be considered in terms of their impact on student learning, professional development programmes need to have an impact on teaching practices for them to make a difference to student learning. It was with these considerations in mind that my study was formulated to examine the effectiveness of teachers' participation in a mathematics networked learning community in terms of participants' classroom teaching behaviours as assessed by their students' perceptions of their classroom learning environment and their attitudes towards mathematics.

This chapter introduces my thesis under the following headings:

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

1.2 CONTEXT OF THE STUDY

This section outlines the context of the study, including mathematics education in Singapore, the professional development of teachers, and the field of learning environments. Besides elaborating the Singapore mathematics curriculum and the Mathematics Framework, it also discusses the current emphasis on mathematics teaching and learning, the various initiatives for transforming the teaching service by leveraging professional development to strengthen teachers' professional knowledge and expertise with a view to enhancing their effectiveness in teaching and learning. The rationale for employing a learning environment framework for evaluating the impact of networked learning communities on student outcomes is presented.

1.2.1 Mathematics Education in Singapore

Mathematics education is important in the national curriculum and it is a compulsory subject in primary and secondary schools in Singapore. On the average, a primary school student has about 200 hours and a secondary school student has between 100 and 150 hours of curriculum time on mathematics in a year. At the secondary level, students who are weaker in mathematics have more mathematics periods. From the time when a child enters the formal school system at Primary 1, he/she will need to learn mathematics up to the end of secondary education. This gives every child about ten years of education in the subject and every Singaporean student would have taken about 1600 hours of instruction in mathematics (Wong & Lee, 2009).

Against this backdrop, the mathematics curriculum in Singapore aims to provide all students with a firm foundation in mathematical concepts and skills. Students with aptitude and interest in mathematics are given opportunities to deepen their knowledge and skills, as well as to develop their passion in the discipline. The curriculum is centrally planned to provide clear guidance on mathematics instruction to teachers, and every effort is made to ensure that mathematics is made accessible to every child in a coherent way.

The Singapore mathematics curriculum framework was first introduced in 1990 in the primary and lower secondary mathematics syllabuses. The framework was updated to reflect new educational emphases and needs in a rapidly-changing world during the curriculum reviews in 2000 and 2003. The revised framework, as shown in Figure 1.1, was extended formally to all levels in 2003.

The curriculum framework encapsulates that the aim of mathematics education in Singapore is to develop students' mathematical problem-solving abilities. Besides

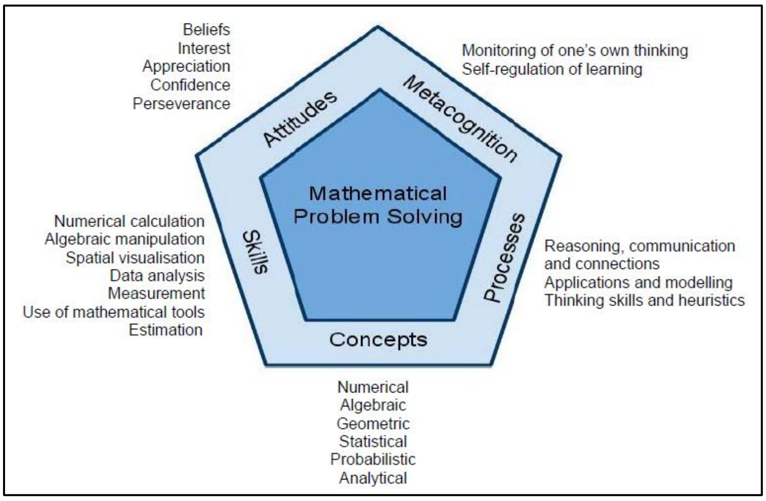


Figure 1.1. The Singapore Mathematics Framework
(Source: Ministry of Education, 2012)

providing a macro perspective of the integral components of the mathematics curriculum, it also guides the implementation of an effective mathematics programme in schools. As shown in the framework, mathematical problem solving is the central focus and purpose for the learning of mathematics in the curriculum. Mathematical problem solving refers to competent, critical and creative use of mathematics to solve problems. Problems can range from simple and routine ones to complicated and non-routine problems, as well as real-world problems that are ill-defined, open-ended and complex in nature.

The development of mathematical problem solving ability requires a good understanding of mathematical concepts, proficiency in mathematical skills and processes, a positive attitude towards mathematics and an awareness of one's thinking processes. These correspond to the five components of the framework (Ministry of Education, 2012) and they are briefly described below:

- Mathematical concepts refer to numerical, algebraic, geometric, statistical, probabilistic, and analytical concepts. Students are exposed to a variety of learning experiences to develop a deep understanding of mathematical concepts. Students engage in hands-on and ICT-based activities to make connections between abstract mathematical concepts and concrete experiences and applications.
- Mathematical skills refer to numerical calculation, algebraic manipulation, spatial visualisation, data analysis, measurement, use of mathematical tools

and estimation. These skills are important in the learning and application of mathematics for students. Mathematical tools include calculators, spreadsheets and software for learning and doing mathematics.

- Mathematical processes refer to reasoning, communication and connections, applications and modelling, as well as thinking skills and heuristics. These processes are integral to acquiring and applying mathematical knowledge. The development of students' mathematical processes should pervade all levels of mathematics learning, and be accomplished through a variety of problems, including non-routine, open-ended and real-world problems.
- Metacognition refers to the awareness of and the ability to control one's thinking processes, particularly the selection and use of problem-solving strategies. It also encompasses both monitoring of thinking during problem solving and regulation of learning behaviours by the students themselves (Wong, 2002). The provision of metacognitive experiences is necessary to help students to improve their problem-solving abilities.
- Attitudes refer to the affective aspects of mathematics learning, such as beliefs about the usefulness of mathematics, interest in learning it, appreciation of the beauty and power of mathematics, confidence in using mathematics, and perseverance in solving a problem. Students' attitudes towards mathematics are shaped by their learning experiences. Hence, making the learning of mathematics meaningful, enjoyable and relevant goes a long way in inculcating these desired attitudes.

The results of both Programme for International Student Assessment (PISA) (2009, 2012) and Trends in International Mathematics and Science Study (TIMSS) (2011, 2007) for Singapore show that a majority of students are very good at applying their knowledge in routine situations, which is partly a consequence of what teachers do and use during their mathematics lessons. For students to achieve higher levels of competency in mathematics, teachers need to nurture students to be active and confident in constructing mathematical knowledge. With reference to the Singapore Mathematics Framework, teaching practice is centred mainly on skills and concepts, with some emphasis on the processes. Much professional development effort is required to empower teachers to engage students in reasoning and explaining a mathematical concept or solution.

1.2.2 Professional Development of Teachers in Singapore

Upon completion of preservice education, teachers in Singapore continue their learning journey through participation in many types of professional development activities. Since 1998, all teachers in Singapore are entitled to 100 hours of training and core-upgrading courses each year to keep abreast with the current knowledge and skills. Funded by the Ministry of Education, the mode for the 100 hours of training can include formal and structured topic-specific seminars, workshops, school-based activities involving curriculum design, discussions of instructional techniques, and day-to-day collaborative activities that enhance teachers' knowledge and skills, such as co-teaching, peer observation and mentoring.

For a long time, the most common traditional type of professional development in Singapore has been inservice courses or one-off workshops that are conducted by experts in the field and without follow-up with the teachers after the course or workshop. These workshops and courses are often in response to curriculum changes and implementation. Participation in these workshops is either mandatory or by nomination by school leaders.

Singapore's educational reforms started in the 1980s and culminated in the formulation of the Thinking Schools Learning Nation initiative in 1997. By realigning education to the new requirements for working and living in the 21st century, it seeks to develop students who are independent learners and good team players, good communicators, willing to take risks, committed to lifelong learning and capable of creative and critical thinking (Goh, 1997). This emphasis on developing every child to his or her fullest potential required schools to be given much greater flexibility and responsibility for how they should teach and manage their students.

The vision of the Thinking Schools Learning Nation initiative places emphasis on the need for teachers to be lifelong learners so that schools keep abreast of advances in knowledge and learning both at the national and international fronts. In giving teachers greater freedom in classroom practices, teachers must be equipped with the essential knowledge and skills. Community-based teacher learning was therefore introduced in 1997 to promote the sharing of effective teaching and learning practices across schools in the various clusters. For the first time, schools in Singapore are divided into four zones: North, South, East and West. Within each zone, schools are grouped into clusters of about 12 to 14 schools, each with a superintendent in charge.

Since 1997, various forms of community-based teacher learning, such as collaborative action research, lesson study and reading groups, mushroomed across the educational system. With the provision of one hour of 'timetabled time' per week for every teacher in 2009 for reflecting on their practices in an attempt to enhance student outcomes, teachers were supported to engage in professional planning and collaboration.

In 2009, the concept of professional learning communities was piloted in 51 schools. Since then, about 95% of Singapore schools have embarked on professional learning communities to build a culture of collaborative and continual professional learning among the teachers in their respective schools. In such schools, teachers meet regularly in learning teams during the one hour of 'timetabled time' for professional learning to focus on how best to improve and enhance student learning. Teachers engage in professional conversations, share best practices, generate or test new ideas to improve classroom practice, or work together to address issues in student learning.

With the launch of the Academy of Singapore Teachers in 2010, networked learning community was adopted as another strategy to raise the level of professional practice in the classroom and expertise across the system. Positioned to strengthen teacher professional development and nurture a culture of professional excellence within the teaching fraternity, the Academy plays a significant role in building the instructional capacity of teachers through various platforms, such as networked learning communities, workshops and symposia. Teachers have opportunities to interact with fellow educators, engage in professional conversations about their teaching, observe classroom teaching and receive feedback on instructional practices. Teacher leadership and ownership of professional development are engendered through providing platforms for teachers to lead other teachers in professional learning in various networks and professional focus groups.

Wong (2013) recognised the importance of teachers widening their repertoire through working on specific teaching techniques in simulated or authentic classroom conditions and under the guidance of more-capable teachers or teacher educators. He also emphasised the need to capitalise on teacher's own teaching experience and their informal exchanges with colleagues as informal pathways for professional learning. He further noted that research into such informal pathways of professional development is still lacking in Singapore. Chua (2009) also highlighted that it is not clear how much of teachers' learning in learning communities is translated into improving or changing their classroom pedagogies in an attempt to improve students' learning. Chua, therefore, concluded that the impact of learning communities on teachers' professional development is indeed an area that warrants further study.

The conceptual frameworks for implementing the professional learning community and the networked learning community in Singapore were largely drawn from research findings in Western literature, and therefore it has been assumed that these findings also apply to the Singapore context without further evidence. Specifically, the characteristics of effective professional development programmes, such as involving teachers in shaping the foci of the programme that is related to their school work (Elmore, 2002; Hawley & Valli, 1999) and grounding teachers' learning in the tasks, questions and problems of practice (Ball & Cohen, 1999), were adopted in these communities. Since 1997, many resources were deployed to support these learning communities to enhance the practices of teachers in an attempt to advance excellence in classroom instruction. This faith in adopting learning communities as a form of professional development for teachers in Singapore was solely based on claims in the literature (Darling-Hammond & Bransford; 2005; Dufour & Eaker, 1998; Dufour et al., 2010; Fullan, 1991; Hargreaves, 2003; Jackson, 2004; Jackson & Temperley, 2007; Liberman & Grolnick, 1997). No empirical study has investigated the processes and outcomes of community-based teacher learning in the local context. While there are reviews and surveys related to these learning communities undertaken by the Academy of Singapore Teachers, they mostly involve implementation issues and teachers' opinions about their professional learning.

What is most glaring is the absence of robust empirical studies that support the hypothesis that learning communities have a significant impact on classrooms and students. This is a gap that needs to be filled by local research.

1.2.2.1 The Mathematics Networked Learning Community in my Study

Unlike the typical professional development in which teachers receive information from experts, the eight teachers in this networked learning community participated with the goal of not only learning from one another, but also learning with one another. Participation in this network was based on the teachers' desire and initiative to improve their teaching practice. Although they were from different schools, they shared the common goal of helping the low-progress learners to learn mathematics. The teachers had five sessions of networked learning conducted over 11 weeks. Facilitated by a Lead Teacher/Mathematics (one of the five teachers in the experimental group) with guidance from me, the first session started off with a teacher showing a video of her mathematics lesson. The members of the learning community then discussed how questions could be more effectively used to probe students' mathematical thinking and justify their solutions. I introduced the strategy of 'Talk Moves' and used another video to show how teachers can generate mathematical reasoning and communication through the five moves of re-voice, repeat, reason, add-on and wait time.

During each meeting, the teachers voluntarily took turns to share their topic of inquiry. Some teachers brought their lesson plans to gather feedback from the community, while others brought student work for collaborative inquiry into the errors made. Some shared how they had used cooperative learning strategies to support group work and Talk Moves to help students to clarify their thinking. Teachers were encouraged to question one another in order to understand each other's point-of-view. In so doing, teachers considered the various perspectives of teachers from the group and the wide range of conditions for learning, such as scaffolding of mathematical discourse, which led to a richer and more coherent lesson design. Focussed on instructional improvement, the teachers engaged in professional conversations to deepen their understanding of the content that they were teaching, the lesson sequence, the design of mathematical tasks, the questions to ask and the anticipated responses of their students.

1.2.3 Theoretical Underpinnings: Learning Environments

According to Dewey (1896), human action is the transaction between a person and his/her natural and social environment, and is in flux as he/she seeks to keep a dynamic balance with the environment that is perpetually changing. He was of the view that "the domain of knowledge and the domain of human action are not separate domains, but are intimately connected: that knowledge emerges from action and feeds back into action, and that it does not have a separate existence or function" (Biesta & Burbules, 2003, p. 15). Based on this perspective that personal knowledge manifests in the way in which they "transact with and respond" (p. 11) to changes in the environment, knowledge and social practice are therefore intimately intertwined as well as mutually constitutive. Parallel to this view is Lewin's (1936) seminal work in non-educational settings, which recognised that both the environment and its interaction with characteristics of the individual are potent determinants of human behaviour.

For high-quality learning of mathematics in classrooms, teachers need to be aware of the learners and the learning context and to deliver the mathematics curriculum through designing and implementing lessons that have meaning and relevance for their students. This requires teachers to have a repertoire of strategies and representations that engage diverse learners. As a professional, the teacher enacts pedagogical content knowledge in the context of learners' individual differences and the changing dynamics of classroom life. Amid this complexity, the teacher participates as a member of a community of practitioners who collaborate in support of student learning and who have the habit of mind to inquire continually into and improve their practice. In an invited special presentation at the International Science, Mathematics and Technology Education Conference, Wong (2013) highlighted the importance of teachers inquiring into their own practices when he argued that "teachers should be reflective practitioners rather that technical workers who carry out the teaching actions in a mechanical or routinized way".

Networked learning community in my study reflected Jackson and Temperley's (2007) view that collaborations within networks encourage teachers to think about, reflect on and challenge individual and collective experiences to deepen their understanding of classroom practices. Participation in networked learning enhances knowledge creation of teachers (Nonaka & Takeuchi, 1995) and strengthens teachers' capacity to initiate and manage changes for continuous improvement (Hargreaves, 1998; Katz & Earl, 2010), which in turn improves student outcomes.

Aldridge et al. (2012) advocate that the perspectives of students can provide a teacher with a valuable source of data for personal reflection and that seeking alternative perspectives through the eyes of teachers' own students can help teachers to view their own practice through the eyes of others. In a similar way, the perspectives of students can provide us with a lens for observing teaching practices that are taking place in the classrooms and with a valuable source of data for assessing the effectiveness of a professional development programme.

Results from the OECD's Teaching and Learning International Survey (TALIS) indicate that professional development, particularly mentoring and networked learning, are effective in educating and inspiring teachers to use student-centred practices (OECD 2009). It also emphasised that a positive learning environment is not only important for students, but also for teachers. For the networked learning community in my study, teachers worked together to 'learn from' and 'learn with' fellow colleagues. They built on one another's ideas to use questions or Talk Moves to involve students in reasoning and explaining their mathematical thinking in the problem-solving process. Cooperation among teachers took various forms, such as the exchange of lesson plans, classroom displays of question starters and feedback on their teaching. As teachers worked collaboratively to discuss ways to create a learning environment in which students propose conjectures, share their thinking and justify their arguments, teachers are encouraged to devote more time to class discussions and group work. Hence, my assumption is that the learning environment experienced by teachers in a networked learning community will be re-enacted by the teachers in their respective classrooms, which would be perceived by their students as they responded to a learning environment questionnaire. My study therefore explored the use of students' perceptions, assessed with a learning environment survey, as process criteria for evaluating teachers' participation in a mathematics networked learning community.

The study reported in my thesis drew on research carried out in the field of learning environments. Contemporary studies of learning environment are largely underpinned by Lewin's pioneering work in utilizing scientific methods and experimentation to investigate social behaviour and his contention that the environment is a determinant of human behaviour. While the notion of person–environment fit has been elucidated in education by Stern (1970), 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 almost 50 years ago with the work of Anderson and Walberg (1968). Since then, it has spawned many diverse research programmes around the world (Fisher & Khine, 2006; Fraser, 2012, 2014) and it has resulted in the creation of *Learning Environments Research: An International Journal.* Past research on learning environments provides a rich resource of conceptual models and research methods that are relevant to my study, as well as valid, economical and widely-applicable assessment instruments from which I could draw to develop an instrument to measure the learning environment.

Learning environment instruments can be used to collect quantitative data for the evaluation of educational programmes. Because every student spends about 6000 hours in the classroom during his/her primary (Primary 1 to 6) school years, students have a large stake in what happens at school and hence their perceptions of classroom experiences are of prime importance. Perceptions of the classroom learning environment have been consistently found to be related to learning outcomes in past research (Aldridge, Fraser & Sebela, 2004) and positive perceptions of the classroom are typically linked to higher achievement and better attitudes (Chionh & Fraser, 2009). For example, Pickett and Fraser (2009) drew on the field of learning environment to evaluate a two-year mentoring programme in science for beginning elementary school teachers in terms of participants' classroom teaching behaviour as assessed by their school students' perceptions of their classroom learning environment.

Guided by this line of thinking, I adopted a learning environment framework for assessing the extent of changes in teaching behaviours as a result of teachers' participation in a mathematics networked learning community in terms of students' perceptions of their classroom learning environments. As highlighted in Section 1.2.2.1, teachers in this learning community shared various instructional strategies, such as Talk Moves and Cooperative Learning Strategies, to encourage students to communicate and clarify their mathematical ideas during problem solving.

My study involved collecting and analysing data to identify differences in the perceptions of students whose teachers were in the networked learning community and those students whose teachers were not involved in such professional learning. I used a modified version of the What Is Happening In this Class? (WIHIC) (Fraser, 1998a) to compare the learning environments of two groups of students. My study also included a scale from the Test of Science Related Attitudes (TOSRA) (Fraser, 1978, 1981) to assess students' attitudes to science

1.3 RESEARCH QUESTIONS

This research was guided by the research problem:

> Does introducing a new mode of professional development, namely, networked learning community, make a difference in teaching behaviour in terms of students' perceptions of their learning environment and students' attitudes to mathematics?

Based on this research problem, three main questions were investigated. In order to answer these three research questions, the Mathematics Classroom Environment and Attitude (MCEA) questionnaire was administered to 375 Primary 5 students in 10 classes in five schools in Singapore.

The first research question was delineated to examine whether the MCEA questionnaire was a valid and reliable measure of students' perceptions of their classroom learning environment and their attitudes to mathematics.

Research Question 1:

Are learning environment scales based on the WIHIC and a newly-constructed scale and an attitude scale based on TOSRA valid and reliable when used with a sample of primary-school mathematics students in Singapore?

After validating the questionnaire, the second research question was delineated to investigate if any relationships exist between students' perceptions of the classroom learning environment and their attitudes to mathematics.

Research Question 2:

Are there associations between learning environment scales and a scale which measures students' enjoyment of mathematics?

Finally, the third research question was delineated to investigate the effectiveness of teachers' participation in mathematics networked learning community.

Research Question 3:

Does teachers' participation in a mathematics networked learning community make a difference in their classroom teaching in terms of their students':

a) perceptions of classroom learning environment

b) attitudes to mathematics?

1.4 SIGNIFICANCE OF THE STUDY

Although networked learning community has been identified as an enabler for achieving the next level of teaching excellence in Singapore, there is no evidence about its impact on teachers' professional development. This poses the following challenges to three main groups of stakeholders, namely, the Academy of Singapore Teachers (a division of the Ministry of Education that oversees the professional development of teachers), the school community and the research community (both local and international). Robust empirical studies of networked learning are crucial in determining the effectiveness of this mode of professional development, which is now promoted and heavily invested in throughout the Singapore educational landscape. The findings from this study also could serve as a basis for informing future research on networked learning communities. The research is likely to provide me with information for reviewing, refining and sharing how networked learning communities are adopted in Singapore. This therefore could translate to better practices in the network and facilitate teachers' professional growth.

Garet et al. (2001) highlighted that literature on the effects of different characteristics of professional development is relatively thin and that there is a need for new, systematic research on the effectiveness of alternative strategies for professional development. My study therefore has the potential to contribute new knowledge to the existing literature on networked learning. The findings from this study could provide a clearer picture of the differences between teachers who have participated in networked learning community and those who have not in terms of the learning environment created by these teachers in their school classrooms. Besides adding an Asian slant to the knowledge base on networked learning, my study is likely to narrow the current knowledge gaps within the international literature of teacher professional learning concerning contexts and outcomes.

Moreover, no previous research in Singapore has employed learning environment criteria to assess the effectiveness of teachers' professional learning in a networked learning community. The study of networked learning communities can be considered as an emerging field relative to other research areas in education. Although evaluations of professional development programmes are usually based on teachers' self-reports about their experiences in workshops, changes in classroom behaviours are stronger indicators of the effectiveness of these programmes. This is supported by research in recent years which has confirmed that the classroom culture has considerable influence on the quality of student learning experiences (den Brok et al., 2006; Fraser, 2012).

Drawing on the findings of Katz and Earl (2010) that creation of new knowledge through networked learning leads to deep conceptual changes and new ways of working in schools and classrooms, my research involved gathering empirical evidence based on students' perceptions of the learning environment created by teachers who had participated in networked learning and teachers' practice (Earl & Kartz, 2007; Jopling & Spender, 2006). With the focus on the impact of professional development (networked learning) on changes in teaching behaviours (learning environment) and student outcomes (attitudes to mathematics) in the networked teachers' classrooms, this study contributed to both fields of research.

1.5 OVERVIEW OF THE THESIS

My study investigated the effectiveness of teachers' participation in a mathematics networked learning community in terms of the learning environments created by these teachers in their school mathematics classrooms, as well as their students' attitudes. The study's conceptualisation, implementation, findings and conclusions are presented in five chapters.

In Chapter 1, the context of my study was presented in terms of mathematics education in Singapore, the professional development of teachers in Singapore, and a discussion of the theoretical underpinnings for the field of learning environments which served as a basis for my research questions and the significance of my study.

Chapter 2 is dedicated to a comprehensive review of the literature related to this study, namely, networked learning community, learning environment and attitudes towards mathematics. The professional development of teachers based on the notion of community of practice is expounded, with a specific focus on existing literature on the effectiveness of networked learning. It also provides an extensive review of the field of learning environments, including a historical perspective, past research and learning environment instruments. This chapter also reviews several definitions of 'attitudes', delineates the meaning of attitudes towards mathematics (Enjoyment) used in my study and considers attitude assessment.

Chapter 3 focusses on the research methods and sample used in this research. It also describes the development of the Mathematics Classroom Environment and Attitude (MCEA) questionnaire, which involved adopting and adapting relevant dimensions and items from the What Is Happening In this Class? and Test of Science Related Attitudes to assess the learning environment and student attitudes, respectively. It also covers the sampling design and the procedures involved in conducting the study and analysing the data collected.

Chapter 4 presents a detailed report of the analyses and results of my study. The chapter begins by examining analyses of data, including the reliability and validity of the MCEA questionnaires when used with a sample of 375 Primary 5 students in Singapore. The effectiveness of teachers' participation in a mathematics networked learning community is gauged by comparing two groups of teachers in terms of pretest–posttest differences in perceptions of the learning environment and students' outcome (attitudes). Associations between the learning environment and students' attitudes towards mathematics are also reported.

Finally, in Chapter 5, some conclusions are drawn based on the results presented in Chapter 4. Besides providing a summary of the thesis, it also highlights the limitations and significance of this research. Last but not least, this chapter also discusses implications for evaluating professional development programmes and proposes some recommendations for future research.

The appendices at the end of the thesis contain several documents that were used in my study. The Mathematics Classroom Environment and Attitude (MCEA) questionnaire used in the study and the instruction for its administration can be found in Appendix A. The information sheets that were given to the teachers, students and parents/guardians are attached in Appendix C to E, respectively. The consent forms that were signed by teachers, students, and parents/guardians are included, respectively, in Appendix E to F. Finally the letters to seek principals' permission for data to be collected from their schools are presented in Appendix G.

Chapter 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of teacher professional development is to increase teachers' professional knowledge and skills in order to improve classroom practices and foster a variety of student outcomes (Fishman et al., 2003; Loucks-Horsley et al., 2003). Generally, educational scholars such as Darling-Hammod and Bransford (2005) agree that professional development should be an ongoing, long-term venture from which teachers can continue to benefit throughout their careers. For example, some studies suggest that the depth of teacher change is related to the duration of professional development (Shields, Marsh & Adelman, 1998; Weiss, Montgomery, Ridgway & Bond, 1998). However, there is much less agreement about what constitutes high-quality professional development or how to assess the quality of professional development (Feiman-Nemser, 2001).

The effectiveness of professional development is usually measured by self-reports of teacher participants or feedback forms on which teachers record their opinions about experiences during the workshop. As there are obvious limitations in self-report data, this study attempted to draw from the field of learning environments in evaluating the effectiveness of teachers' participation in a mathematics networked learning community in terms of the participants' classroom teaching behaviours as assessed by their students' perceptions of their classroom environments.

This chapter reviews literature on networked learning community (Section 2.2) to provide an overview of professional development of teachers based on the notion of community of practice. Students' perceptions of their learning environment were gathered in my study through a learning environment instrument to evaluate changes in classroom practice as a result of teachers' participation in a networked learning community. Therefore, Section 2.3 reviews the history of learning environments research, discusses some of the most commonly-used learning environment instruments, and provides a more in-depth review of the What is Happening In this Class? (WIHIC) because it was the main instrument from which scales were selected for my study. Besides reviewing research involving classroom environment instruments, Section 2.3 also discusses in detail two past lines of research: evaluation of educational innovations; and associations between student outcomes and environment. Because students' attitudes to mathematics were another indicator of the effectiveness of networked learning in my study, Section 2.4 discusses some definitions of attitude and its relation to mathematics learning. This section concludes with a review of approaches to and instruments for evaluating of student attitudes.

2.2 NETWORKED LEARNING COMMUNITY

2.2.1 Professional Development

Lassonde and Israel (2010) defined professional development as participation in opportunities that result in the acquisition of new knowledge, understandings, skill or strategies that enhance and build upon current knowledge. According to them, the goals for professional development are to advance students' learning and for teachers to explore options, gain new perspectives and ideas, and acquire knowledge and skills so as to empower teachers to independently carry out new approaches by applying learned classroom practices. Professional development can take various forms: collective or individual development, continuing education, preservice and inservice education, group work, team curriculum development, peer collaboration, and peer support. According to Fullan (1991), professional development can therefore be summarised as "the sum total of formal and informal learning experiences throughout one's career" (p. 326).

In Singapore, an internal review of professional development for teachers revealed that, despite the many workshops and courses provided for teachers, these professional growth opportunities typically do not lead to significant changes in Singapore classrooms. This seems to resonate with research which shows that professional development in the form of one-day workshops has very little effect on changes to the ways in which teachers teach and to what students learn (Gullickson, Lawrenz, & Keiser, 2000; MacKenzie, 1991). Reasons for this are the lack of follow-up and inconsistencies in implementation. According to Joyce and Showers (1983), effective programs require sustained, ongoing efforts with proper funding. Participants must be acquainted with what Joyce calls the 'problem of transfer'. As teachers learn new skills and attitudes, they should consider the obstacles to implementing these skills successfully in their classrooms. Before trying new skills in their classrooms, teachers should have ample opportunity to practice the skills in relatively controlled and safe environments until a significant degree of confidence and 'executive control' has been acquired. 'Executive control' refers to teachers learning how to learn and how to adjust new strategies as they practise them in real situations. Over the succeeding weeks and months, 'coaching' by peers and sustained practice are essential if the new approaches are to take root (Joyce & Showers, 1983, pp. 15–22).

Beyond teachers' acquisition of new skills or knowledge, professional development today also means providing opportunities for teachers to reflect critically on their practice and to fashion new knowledge and beliefs about content, pedagogy and learners (Darling-Hammond & McLaughlin, 2011). Besides deepening one's content knowledge and pedagogical content knowledge, effective professional development provides teachers with a clear view of the connections between what they learn during professional development and their classroom practice. Moving beyond the transmission of knowledge and skills, professional development therefore facilitates teachers in developing the reflective skills needed to gain new insights into their pedagogical approaches and teaching practice.

2.2.2 Learning Community

In the literature, there is a variety of meanings to the term 'learning community'. Barth (1990, p. 9) described a community of learners as "a place where students and adults alike are engaged as active learners in matters of special importance to them and where everyone is thereby encouraging everyone else's learning". He also explored the role of teachers and principals as learners and the importance of cooperative and collegial relationships as important aspects of community.

In *Recreating Schools*, learning community is described by Myers and Simpson (1998) as "cultural settings in which everyone learns, in which every individual is an integral part, and in which every participant is responsible for both the learning and the overall well-being of everyone else" (p. 2). In the same vein, Mitchell and Sackney (2000, p. 9) characterise a learning community as a group of people who take an active, reflective, collaborative, learning-oriented and growth-promoting approach towards the mysteries, problems and perplexities of teaching and learning. A learning community is therefore one that promotes and values learning as an ongoing, active, collaborative process with dynamic dialogue by teachers.

Besides the importance of individual teachers' professional learning, the concept of community also focuses on the professional learning within a community context – a community of learners – and the notion of collective learning. In describing strong professional learning communities, Hargreaves (2003, p. 170) makes no distinction between networked learning communities and professional learning community. According to Hargreaves, a strong professional learning community:

> ...brings together the knowledge, skills and dispositions of teachers in a school or across schools to promote shared learning and improvement. A strong professional learning community is a social process for turning information into knowledge.

In the Singapore context, the distinction is based on whether the collaboration is among teachers within the same school (professional learning community) or between teachers from different schools (networked learning community). A network is viewed as a group of organisations working together to solve a problem or issue of mutual concern that is too large for any one organisation to handle on its own (Mandell, 1999). In this respect, networks could help individuals and schools to accomplish what they cannot accomplish on their own. Networks are premised on the belief that, when professionals come together and share their expertise, they build new knowledge, with that new understanding leading to a change in practice and ultimately improved practice and student achievement. In my study, networked learning community refers to teachers from different schools who work on an instructional issue to improve the teaching of mathematics.

2.2.3 Networked Learning

The concept of networked learning is grounded in a situative perspective on cognition and learning. Knowing and learning are constructed through participation in the discourse and practices of a particular community, and are situated in particular physical and social contexts (Greeno, 2003; Lave & Wenger, 1991). Despite the limited research base on how to provide high-quality teacher professional development, there is a growing consensus about the value of creating opportunities for teachers to work together on improving their practice and locating these learning opportunities in the everyday practice of teaching (Ball & Cohen, 1999; Putnam & Borko, 1997; Wilson & Berne, 1999).

From a situative perspective, there are two views on learning. Firstly, it is an individual process of coming to understand how to participate in the discourse and practices of a particular community. Secondly, it is a community process of refining norms and practices through the ideas and ways of thinking that individual members bring to the discourse (Lave & Wenger, 1991). In this theoretical framework, individual and collective knowledge emerge and evolve within the dynamics of the spaces that people share and within which they participate. It is about forming a community of practice (Wenger, 1998) with fellow educators that is held together by their common pursuit of a shared learning experience. They develop practices (resources, frameworks and perspectives) which help to sustain their mutual engagement in the work or activity. Members in this community learn by "engaging in and contributing to the practice of their communities" (p. 7). By engaging in meaningful practices, they become involved in discussions and actions that make a difference to the communities that they value. The concept of community is fundamental in understanding how professional development can take place in a network.

Networked learning is at the heart of collaborative capacity building. Stager (1995) suggests collaborative problem solving as the most effective form of professional development. There is considerable research to support that collaborative group learning is the most powerful kind of professional development (Garmston & Wellman, 1999; Johnson & Johnson, 1999; Zeichner, 2003). It is a form of learning that encompasses the notion of building capacity within schools and networks (Hopkins & Jackson, 2002) as well as promoting system-wide learning. According to Jackson (2004), networked learning occurs when people from different schools in a network engage with one another to enquire into practice, to innovate, to exchange knowledge and to learn together. Networks are based on the beliefs that you cannot improve student learning without improving teacher learning (Fullan, 1993).

Lieberman and Grolnick (1997) suggest that learning to collaborate is about sharing power, knowledge and influence. Collaboration involves a shared exploration of a problem based on negotiation of knowledge found in literature studied by peers and shared among the group. This is extended by comparisons with previous classroom experiences which are made explicit as part of the group's ongoing discussions. Ideas, themes and issues suggested by the literature are integrated into the context of the group's shared experiences. As members come from diverse backgrounds and varied professional contexts, making inferences about each other's sharing enables close examinations of concepts across settings and cultures.

McLaughlin and Talbert (1993) argue that, for teachers to be successful in changing their practice, they need opportunities to participate "in a professional community that discusses new teacher materials and strategies and that supports the risk-taking and struggle entailed in transforming practice" (p. 15). Conversations among teachers in these communities should promote a critical examination of teaching practice, as well as enabling teachers to collectively explore ways of improving their teaching and to support one another as they work to transform their practice. Establishing trust among teachers in the learning community is critical for fostering such conversations. It is important to develop communication norms that enable challenging discussions about teaching and learning and to maintain a balance between respecting individual teachers and critically analysing issues in their teaching (Frykholm, 1998; Seago, 2004).

Analyses of people's functioning in everyday contexts show that expertise, in the sense of the ability to perform some tasks or set of tasks, is usually distributed across people and artifacts in the environment (Lave, 1988; Salomon, 1993). When teachers work collaboratively, they can form a system that is capable of accomplishing goals that no individual could accomplish alone. Networks are locations in which specialized knowledge can be created and transferred within collaborative contexts (Jackson, 2004). In the field of teacher professional development, some key studies show that teacher networks add value for the implementation of innovations, teacher development, school leadership and improved teaching practices (Dresner & Worley, 2006; Katz, Earl & Jaafar, 2009; Lieberman &Wood, 2002).

To date, studies have focussed on the values and purpose of networked learning communities (Cousin & Deepwell, 2005; Day, Hadfield, & Kellow, 2002; Jopling, 2006; Katz & Earl, 2007; Lieberman, 2000) and also the principles and features for fostering successful networked learning communities (Jackson & Temperley, 2007; Katz & Earl, 2010; Wenger, 1998). Because no previous published study has reported negative results for networked learning communities, inevitably my literature review is mainly about the positive impact of learning communities on teachers' professional development.

2.2.4 Effectiveness of Networked Learning

The theory of action that underpins the Aporia Investigation on the Networked Learning Communities Programme in England is that there is a logical relationship between what happens in networked learning communities and their ultimate goal of enhanced learning for pupils (Earl et al., 2006). This means that changes in pupil learning depend on how teachers think about teaching and learning and how they are enacted in classrooms. Knowledge creation in networks should result in visible and substantial changes in how teachers think, what they do in classrooms and how they do it. These changes that teachers make in their practices have been described by Hargreaves (1998) as the mechanisms for enhancing pupils' learning and their long-term successes. Such conceptual change in teachers occurs through interaction within and across schools in the networked learning community.

Wohlstetter and Smith (2000) suggest that schools working together in networked learning community are more likely to be effective in enhancing organisational capacity and improving student learning than individual schools working alone.

Networks have been found to contribute to teacher motivation (Firestone & Pennell, 1997). Lieberman and Wood (2003) also found that involvement in teacher networks promotes learning for teachers, feelings of empowerment and a sense of belonging. Such support from members in a network is especially important in cases for which teachers feel a sense of isolation within their own schools.

There are very few studies that address the impact of network participation on pupil learning. Hwang et al. (2004) reported that there is very little research into the way in which networks work in educational contexts or about what to emphasise to foster successful and productive networked learning in education. Bell et al. (2005) found only 11 studies of networked learning communities with evidence of impact on pupils. Three of these were related to attainment, whereas the other studies focused on pupils' engagement, motivation, social skills and attendance. Their review of networked learning communities concluded that networks can be a highly effective vehicle for improving learning and attainment (p. 65).

Katz and Earl (2010, p. 43) reported that they were surprised that fewer than half of the teachers in 662 schools indicated that there had been changes in thinking about teaching and classroom practices. They found that only about 50% of the teachers used innovative approaches in their classrooms or used common practices with their colleagues. Only between 20% to 40% of teachers responded that they had made what they know explicit for others, changed the way they think about relationships with their pupils, curriculum and teaching, or unlearned previously-held ideas and approaches. They also reported that schools were not sufficiently engaged in the network for it to influence their daily routines or practices in order to make a difference in pupils' learning. Changes in pupil learning related to teachers' participation in networked learning depend on the activities and learning that take place in the network that have an impact on the working lives of teachers.

This literature review suggests that, in the networked learning community in this study, it would be of utmost importance to convince teachers to inquire into their classroom teaching and to have commitment to improve their practice. With the limited evidence available about the impact of teachers' participation in networked learning community on students' learning, my study provided the research community with another means of measuring the impact of networked learning community and this is extensively discussed in Section 5.4.

2.3 LEARNING ENVIRONMENTS

2.3.1 Background of the Field of Learning Environments

The study of learning environments has its roots in social psychology in the United States of America (USA). Researchers, such as Hartshorne and May (1928) proposed that behaviour is specific to the situation and this is a central concept in learning environment research. The idea that behaviour is situational is the very reason why contemporary research often investigates people within their environment.

Fraser (1998a) conceptualised a learning environment as referring to the social, psychological and pedagogical contexts in which learning occurs and which affect student achievement and attitudes. The learning environment is the overall climate and structures of the classroom that influence how students respond to and remain engaged in learning tasks. It is also the context in which teaching acts are carried out (Arends, 2001).

Lewin's (1936) work on field theory acknowledged that the environment and its interaction with individuals' personal characteristics are strong determinants of human behaviour. The Lewinian formula, $B = f(P, E)$, laid the foundation for research strategies in which behaviour is considered to be a function of both the person and the environment. In other words, human behaviour is co-determined by the environment and the personal characteristics of an individual.

Murray (1938) proposed a need–press model to describe an individual's personal needs and environmental press. He defined needs as the specific, innate and personal requirements of an individual, such as personal goals. An individual's need to achieve these goals, or drive to attain them, is also a factor in an individual's personality. The presses are the environmental factors beyond an individual's control that either enhance or inhibit an individual's achievement of personal needs and goals. Murray introduced the term 'alpha press' to describe the environment as assessed by an external observer and the term 'beta press' to describe the environment as perceived by members of that environment. Murray's needs–press model complemented Lewin's formula by depicting personality characteristics as goal-oriented and environmental characteristics as external.

Building on Murray's distinction between *alpha* press and *beta* press, Stern, Stein and Bloom (1956) further distinguished the unique view that each person has of the environment (*private* beta press) from the shared view that members of a group hold about the environment (*consensual* beta press). Private and consensual beta press could differ from each other, and both could differ from the detached view of alpha press of a trained non-participant observer. In classroom environment studies, researchers therefore need to decide whether their analyses will be based on the perception scores obtained from the individual students (private press) or whether these will be combined to obtain the average of the environment scores of all students within the same class (consensual press).

Herbert Walberg and Rudolf Moos pioneered the development of instruments to measure perceptions of environments in the late 1960s. Studies of the social climate of psychiatric wards (Houts & Moss, 1969), state mental hospitals (Gripp & Magaro, 1971) and correctional schools (Moos & Houts, 1968; Wenk & Moos, 1972) led to the development of a theory to sort human environment dimensions into three areas: relationship dimensions, personal development dimensions and system maintenance and system change dimensions (Moos, 1974). Relationship dimensions are those relating to the nature and intensity of personal relationship. Personal development dimensions refer to the path through which knowledge development progresses. System maintenance and system change dimensions refer to the orderliness, clarity, control and responsiveness to change in the environment (Moos & Trickett, 1987). These three areas of human environment dimensions have been fundamental in the study of learning environments. Moos' studies led to the development of the Classroom Environment Scale (CES) (Moos & Trickett, 1974, 1987; Trickett & Moos, 1973) which allowed researchers to study the specific learning environment related to schools.

Walberg and Anderson (1968) developed the Learning Environment Inventory (LEI) as part of a research and evaluation associated with Harvard Project Physics. This archetypal questionnaire was originally used to investigate students' perceptions of the classroom climate associated with two different delivery methods in a physics course for secondary students. Walberg found that students could make valid judgements about their learning environments that were useful in learning environment research (Dorman, 2002). This view that students' judgements are valid and useful is a central concept in contemporary educational research which enables student voices to be heard.

The pioneering work of Lewin and Murray, which was followed by Moos and Walberg, were the foundations for the genesis of the study of learning environments. Moos' work with the CES and Walberg's work with the LEI provided valuable tools that inspired and guided further research. With more studies being conducted since then, the field of learning environments gained international acceptance and became established as important area to be studied. This development of learning environment as a field of study led to the publication of the journal, *Learning Environments Research: An International Journal* (Fraser, 1998b) and books on learning environment such as *Contemporary Approaches to Research on Learning Environments: Worldviews* (Fisher & Khine, 2006). Extensive literature reviews focusing on learning environments include book chapters in the *Handbook of Research on Science Education* (Fraser, 2007, 2014), the *Second International Handbook of Science Education* (Fraser, 2012) and the *Handbook of Research on Science Education Volume II* (Fraser, 2014).

2.3.2 Learning Environment Instruments

Prior to the development of learning environment instruments, studies involved the use of observation techniques and the perceptions of the viewers. Fraser (2012, p. 1192) argued that defining the classroom environment in terms of the shared perceptions of the students has an advantage over direct observations of classroom setting because students have experienced many different learning environments and have had enough time in a class to form accurate opinions. Studies have also shown that students' perceptions of a wide range of instructional and social cues relevant to their own learning can be acquired within the time of a classroom lesson (Walberg & Anderson, 1972). These findings are mirrored by Fraser (1991) and Fraser, Anderson and Walberg (1982) when they highlighted several advantages in using perceptual measures with students for assessing classroom environment relative to observations made by external observers:

- Some important data that could be missed by an external observer or simply considered unimportant could be picked up because the class is described through the eyes of actual participants.
- The participants within the classroom (teacher and students) are the best people for assessing the classroom environment.
- Students' observations are based on a longer time period than those of an external observer.
- Perceptions of the whole class are gathered rather than those of only one or two observers.
- Perceptual measures are able to account for more variance in student learning outcomes than directly observed variables.

As mentioned earlier, the Learning Environment Inventory (LEI) was first developed and validated based on research and evaluation associated with Harvard Project Physics (Walberg, 1968). This instrument asks students for their perceptions of the whole-class environment. This study demonstrated that individual students' satisfaction with the climate of a classroom were associated with learning, verifying that climate variables were good predictors of student learning outcomes (Anderson & Walberg, 1972).

During the same period, Moos and Trickett (1974) developed a series of environment measures which included the Classroom Environment Scale (CES). This instrument also asked students for their perceptions of the learning environment of the class as a whole. As research grew internationally, the LEI and CES were translated into other languages and provided considerable impetus for the study of classroom learning environments. Besides being extensively used for a variety of research purposes, the two questionnaires also provided models for the development of a range of instruments over the next two decades or so (Fraser, 1994). Despite the growth in the field of learning environments into the international arena, as well as into various subject domains, it is interesting to note that Moos' three areas (relationship, personal development, and system maintenance and system change) have continued to be a major influence during the design of learning environment research instruments. Table 2.1 gives an overview of ten frequently-used learning environment instruments and shows the name of the instrument, the educational level for which it is best suited, its authors, the year when it was developed, and the number of items per scale. It also classifies each scale according to Moos' scheme.

2.3.2.1 Learning Environment Inventory (LEI)

The Learning Environment Inventory (LEI) was first developed and validated in association with research on Harvard Project Physics (Walberg & Anderson, 1968). This historically-important questionnaire has 105 items, with seven items in each of the 15 scales of Cohesiveness, Friction, Favouritism, Cliqueness, Satisfaction, Apathy, Speed, Difficulty, Competitiveness, Diversity, Formality, Material Environment, Goal Direction, Disorganization and Democracy. There are four responses to each statement: Strongly Agree, Agree, Disagree, and Strongly Disagree. To ensure consistency of students' responses, some items are reverse scored (Fraser, Anderson, & Walberg, 1982; Walberg & Anderson, 1968).

2.3.2.2 Classroom Environment Scale (CES)

The Classroom Environment Scale (CES) was created by Rudolf Moos of Stanford University after much work in different environments which included hospitals, prisons and schools. The original version of the CES with 242 items comprising 13 conceptual dimensions (Trickett & Moos, 1973; Moos & Trickett, 1974) was eventually revised to a final version with nine scales. There are 10 items of True–False response format in each of the nine scales assessing Involvement, Affiliation, Teacher Support, Task Orientation, Competition, Order and Organisation, Rule Clarity, Teacher Control and Innovation. The CES has separate Actual and Preferred forms. The Actual form assesses students' perceptions of their actual learning

Table 2.1 Overview of Scales of Ten Classroom Environment Questionnaires

Instrument	Level	Year Developed & Authors	Items per scale	Scales Classified According to Moos' Scheme: Relationship Dimensions	Personal Development Dimensions	System Maintenance and Change Dimensions
Learning Environment Inventory (LEI)	Secondary	1968 Walberg & Anderson	7	Cohesiveness Friction Favouritism Cliqueness Satisfaction Apathy	Speed Difficulty Competitiveness	Diversity Formality Material Environment Goal Direction Disorganisation Democracy
Classroom Environment Scale (CES)	Secondary	1974 Moos & Trickett	10	Involvement Affiliation Teacher Support	Task orientation Competition	Order and Organisation Rule Clarity Teacher Control Innovation
My Class Inventory (MCI)	Elementary	1981 Fisher & Fraser	6–9	Cohesiveness Friction Satisfaction	Difficulty Competitiveness	
Questionnaire On Teacher Interaction (QTI)	Primary/ Secondary	1985 Wubbels, Creton, & Hoomayers	8–10	Helpful/friendly Understanding Leadership Student Responsibility and Freedom Dissatisfied Admonishing Uncertain Strict		
Science Laboratory Environment Instrument (SLEI)	Upper Secondary/ Higher Education	1995 Fraser, Giddings & McRobbie	7	Student Cohesiveness	Open-endedness Integration	Role Clarity Material Environment
Constructivist Learning Environment Survey (CLES)	Secondary	1995 Taylor, Dawson & Fraser	7	Personal Relevance Uncertainty	Critical Voice Shared Control	Student Negotiation
What Is Happening In this Class? (WIHIC)	Secondary	1996 Fraser, McRobbie & Fisher	8	Student Cohesiveness Teacher Support Involvement	Investigation Task Orientation Cooperation	Equity
Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI)	Upper Secondary	2004 Aldridge, Dorman & Fraser	8	Student Cohesiveness Teacher Support Involvement	Investigation Task Orientation Cooperation	Equity Differentiation Computer Usage Young Adult Ethos

(continued)

Table 2.1 (continued)

Instrument	Level	Year Developed & Authors	Items per scale	Scales Classified According to Moos' Scheme: Relationship Dimensions	Personal Development Dimensions	System Maintenance and Change Dimensions
Constructivist-Oriented Learning Environment Survey (COLES)	Upper Secondary	2011 Aldridge, Fraser, Bell & Dorman	8	Student Cohesiveness Teacher Support Involvement Personal Relevance	Task Orientation Cooperation	Equity Formative Assessment Assessment Criteria Differentiation Young Adult Ethos
Place-Based and Constructivist Environment Survey (PLACES)	Elementary	2013 Zandvliet	3	Relevance/ Integration Group Cohesiveness Student Involvement Open Endedness	Critical Voice Shared Control	Student Negotiation Environmental Interaction

Adapted from Fraser (2012)

environments and the Preferred form assess the learning environment that students would prefer (Fisher & Fraser, 1983; Moos, 1979; Moos & Trickett, 1974, 1987).

2.3.2.3 My Class Inventory (MCI)

The My Class Inventory (MCI) is a simplified version of the LEI. Specially developed for use with children aged 8–12 years old, it has only five of the LEI's original scales (Fisher & Fraser, 1981; Fraser, Anderson & Walberg, 1982). The wording was simplified for easier reading and it has only a two-point response format (Yes–No) instead of the four responses in the LEI. Students' responses are written on the questionnaire itself instead of a separate response sheet to avoid errors in transferring responses from one sheet to another. The final version of the MCI has 38 items in the five scales: Cohesiveness, Friction, Satisfaction, Difficulty and Competitiveness. Another version of the MCI has a three-point response format comprising Seldom, Sometimes, Most of the Time (Goh, Young & Fraser, 1995), while a short form of the MCI has 18 items in the four scales of Cohesion, Competitiveness, Friction and Satisfaction (Sink & Spencer, 2005).

The MCI has been cross-validated and used in a number of studies. For example, Majeed, Fraser and Aldridge (2002) used a modified version of MCI with 1,565 lower-secondary mathematics students in 81 classes in 15 government schools to investigate the classroom learning environment and its association with student satisfaction among students in Brunei Darussalam. This study showed a satisfactory factor structure for a refined three-scale version of the MCI comprising Cohesiveness, Difficulty and Competition. The researchers also reported that male and female students had different perceptions of their learning environment and that students' satisfaction was greater in classrooms with a more positive learning environment.

Mink and Fraser (2005) used the MCI to evaluate a K–5 mathematics programme which integrates children's literature. Based on a sample of 120 fifth-grade students, the MCI showed satisfactory internal consistency reliability and discriminant validity and was able to differentiate between the perceptions of students in different classes. This study also reported that students' satisfaction was greater in classrooms with a more positive learning environment.

Using a sample of 2,835 grade 4–6 students in an urban school district in Washington State, Sink and Spencer (2005) found that an 18-item revision of the MCI (assessing cohesiveness, competitiveness, friction and satisfaction) was psychometrically sound. Based on the sound reliability of MCI, the researchers advocate the use of the MCI as an accountability tool for elementary-school counsellors.

In Texas, the MCI was used in an evaluation of science kits among a sample of 588 grade 3–5 students by Scott Houston, Fraser and Ledbetter (2008). Besides attesting to the validity of the MCI, data analyses suggested that using science kits was associated with a more positive learning environment in terms of student satisfaction and cohesiveness.

2.3.2.4 Questionnaire on Teacher Interaction (QTI)

Following the pioneering research of Walberg and Moos in the USA, Wubbels and his colleagues began ambitious programmatic research in the Netherlands which focussed specifically on the interaction between teachers and students in the classroom. The QTI was adapted from the work by Leary (1957) on interpersonal behaviours in clinical psychology. The theoretical basis of QTI is a systems perspective on communication processes (Watzlawick, Beavin, & Jackson, 1967) and a theoretical model of proximity (Cooperation – Opposition) and influence (Dominance – Submission) which acknowledges that behaviours from the students might affect teachers' interactions with them. Conversely, the teacher's interactions might affect students' behaviours. This suggests that the behaviours of participants influence each other mutually.

There are 77 items divided between 8 scales in the original version of the QTI. A short version of the QTI has a total of 48 items in 8 scales, with only 6 items in each scale. Each of the eight scales describes a different behaviour aspect: Leadership, Helpful/Friendly, Understanding, Student Responsibility and Freedom, Uncertain, Dissatisfied, Admonishing and Strict behaviour. Responses to the QTI are based on a five-point frequency scale ranging from Never (0) to Always (4).

Although research with the QTI began at the senior high-school level in the Netherlands, the instrument has been translated into various languages and cross-validated in various grade levels in the USA, Australia and Asian countries. Some examples include a study in Indonesia with a sample of 422 private university students from 12 classes to validate a modified and translated version of the QTI and to investigate associations between students' perceptions of instructor–student interactions of achievement and attitudes (Fraser, Aldridge, & Soerjaningsih, 2010). In Turkey, data from 7484 grade 9–11 students from 278 science classes confirmed the reliability and validity of a Turkish adaption of the QTI (Telli, den Brok, & Cakiroglu, 2010). This study suggests that Turkish teachers were perceived by their students as very cooperative and moderately dominant. Quek, Wong and Fraser (2005) validated an English version of the QTI with 497 gifted and non-gifted secondary school chemistry students in Singapore and their findings showed some stream (i.e. gifted and non-gifted) and sex differences in QTI scores.

In the Netherlands, when Wubbels et al. (1991) used the QTI to compare students' and teachers' perceptions, they found that both students and teachers preferred a more positive classroom environment than what was perceived as being actually present. Their second finding was that teachers tended to perceive the classroom environment more positively than did their students in the same classroom. Their study also showed that there were statistically significant relationships between teacher–student interactions and student outcomes. Wubbels and Levy's edited book (1993) reports the validity and reliability of the QTI when used in the Netherlands.

Wubbels and Brekelmans (1998) found medium to strong associations between teacher behaviour and student outcomes in their studies of teacher–students relationships in the classroom. These relationships for affective aspects were stronger than for cognitive outcomes. Leadership, Helpful/friendly and Understanding behaviours were positively related to student outcomes, but Uncertain, Dissatisfied, and Admonishing behaviours were negatively related to outcomes.

Wubbels and Brekelmans (2012) claim that the way in which a teacher interacts with students is not only a predictor of student achievement, but is also related to factors such as teacher's job satisfaction. Although affective variables are important in traditional classrooms, it is even more important in constructivist classrooms, where emotion plays a more prominent role. They highlighted the importance of changing teachers' behaviour to improve science teaching through staff development and inservice training programmes.

2.3.2.5 Science Laboratory Environment Inventory (SLEI)

The Science Laboratory Environment Inventory (SLEI) was developed to measure students' perceptions of the science laboratory classroom learning environment (Fraser, Giddings, & McRobbie, 1995). The initial version contained 72 items in the seven scales of Teacher Supportiveness, Student Cohesiveness, Open-Endedness, Integration, Organization, Rule Clarity and Material Environment. In the final version of SLEI, there are 35 items in the five scales of Student Cohesiveness, Open-Endedness, Integration, Rule Clarity, and Material Environment. There are seven items in each of the five scales. The five alternative responses are Almost Never, Seldom, Sometimes, Often, and Very Often. There are two forms: the personal and the class form. Both have actual and preferred versions.

The SLEI was field tested and validated simultaneously with a sample of over 5,447 in 269 senior high school and university classes in the same six countries: the USA, Canada, England, Israel, Australia, and Nigeria (Fraser & McRobbie, 1995). It was subsequently cross-validated with 1,594 senior high school students in 92 classes in Australia (Fraser & McRobbie, 1995) and 489 senior high school biology students in Australia (Fisher, Henderson & Fraser, 1997).

In another study, the SLEI was used with a sample of 761 high-school students in 25 classes in south-eastern USA to evaluate the use of anthropometric activities in terms of student outcomes and classroom environment (Lightburn & Fraser, 2007). Findings from this study suggested that students' attitudes to science were more favourable in laboratory classes where there was a strong integration between concepts covered in theory classes and laboratory classes.

The SLEI was translated into Korean and administered to a sample of 439 students: 99 science-independent stream students, 195 science-oriented stream students, and 145 humanities stream students. Data analyses confirmed the validity, reliability, and ability of Korean-version SLEI to differentiate between the perceptions of students in different classrooms (Fraser & Lee, 2009).

In Singapore, the validity of the English version of the SLEI was also confirmed through a study by Wong and Fraser (1996) involving 1592 Grade 10 chemistry students from 56 classes in 28 schools. The English version of the SLEI was also cross-validated in a study involving 497 gifted and non-gifted chemistry students in Singapore (Quek et al., 2005). Statistical analysis of the data revealed that the SLEI was valid, reliable and useful within the context of the study.

2.3.2.6 Constructivist Learning Environments Survey (CLES)

The Constructivist Learning Environment Survey (CLES) (Taylor, Fraser, & Fisher, 1997) was developed to assess the extent to which a classroom's environment is consistent with constructivist epistemology, which views learning as a process in which individuals makes sense of the world based on their prior knowledge and active negotiation of knowledge. The CLES has 36 items with five response alternatives ranging from Almost Never to Almost Always. The CLES assesses

Personal Relevance, Uncertainty Critical Voice, Shared Control and Student Negotiation. Teachers are empowered to reflect on their epistemological assumptions and revise their teaching practice based on insights gleaned from students' responses to the CLES. The CLES has been validated in a number of studies and in a number of countries.

Kim, Fisher and Fraser (1999) translated the CLES into the Korean language and cross-validated it with a sample of 1,083 students in 24 grade 10 science classes. They reported a sound factor structure and high reliability for the Korean version and established statistically significant relationships between classroom environment and students' attitudes to science. Their study also suggested that students who had experienced a new curriculum perceived a more constructivist learning environment than those students who had not.

The CLES was validated and used in South Africa to help teachers to become more reflective in their mathematics classroom practice (Aldridge, Fraser, & Sebela, 2004). Analysis of data gathered from a sample of 1,864 Grade 4–9 students in 43 classes with 18 teachers from 6 schools confirmed the validity and reliability of the CLES when used in mathematics classes in South Africa. Spinner and Fraser (2005) used the CLES with 119 students from 6 classes to assess the level of constructivist teaching and learning practices in Florida.

Nix, Fraser and Ledbetter (2005) reported strong support for the validity of the CLES based on a diverse sample of 1,079 students in 59 science classes in North Texas. Using this instrument to evaluate an innovative science teacher professional development programme (known as the Integrated Science Learning Environment, ISLE, model), it was found that the students of these teachers perceived their classrooms more favourably than did the students of other teachers.

Ogbuehi and Fraser (2007) reported that, with a sample of 661 mathematics students from 22 classrooms in California, the CLES and two other instruments exhibited satisfactory factorial validity, internal consistency reliability, discriminant validity and the ability to distinguish between classes. In the same vein, statistical analyses based on a sample of 739 Grade K–3 science students in Miami using both the modified Spanish version of CLES and the English version supported the validity of both versions when used with young children (Peiro & Fraser, 2009).

Koh and Fraser (2014) used a modified version of CLES to evaluate the effectiveness of a pedagogical model, Mixed Mode Delivery (MMD), in terms of the CLES's five scales of Personal Relevance, Uncertainty, Critical Voice, Shared Control and Negotiation. Using a sample of 2,216 secondary school students taught by preservice teachers in an MMD group and 991 students in a control group, comparisons were made between these two groups based on the relative magnitudes of the gap between the actual and preferred learning environment in students' school classrooms. The findings supported the positive impact of using MMD in terms of students' perceptions of their classroom environments for all CLES scales.

2.3.2.7 What Is Happening In this Class? (WIHIC)

In my study, the What Is Happening In this Class? (WIHIC) was used as a basis to craft the Mathematics Classroom Environment and Attitude Questionnaire (MCEA). Therefore, a more detailed literature review is undertaken of the development, validation and use of WIHIC in Section 2.3.3.

2.3.2.8 Technology-Rich Outcomes-Focused Learning Environment Inventory

The Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) is designed to monitor educational programmes aimed at promoting outcomes-focused and ICT-rich classroom environments. This questionnaire comprises all of the WIHIC's seven scales of Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, and Equity, together with three extra scales (Differentiation, Computer Usage and Young Adult Ethos). The TROFLEI contains 80 items altogether with 8 items belonging to each of 10 scales. The instrument uses a five-point frequency response scale with response options of Almost Never, Seldom, Sometimes, Often, and Almost Always. The students can be asked to indicate their responses to both the actual and preferred versions of the TROFLEI.

According to Aldridge, Dorman and Fraser (2004), the TROFLEI has been found to be valid and reliable based on data obtained from a sample of 1,249 high school students from Western Australia and Tasmania who responded to both the actual and preferred forms of the TROFLEI. Another study, which was conducted with 4,146 students from 286 classes in Australian secondary schools further supported the validity and reliability of the TROFLEI and also established a typology of classrooms based on students' perceptions of classroom environment (Dorman, Aldridge & Fraser, 2006).

The TROFLEI was used in monitoring and evaluating the success of a new school in promoting outcomes-focused education among a sample of 1,035 senior high school students from 80 classes. Changes in students' perceptions of their classroom environments were monitored over a period of 4 years. Analysis of data gathered using TROFLEI supported the efficacy of the school's educational programmes (Aldridge & Fraser, 2008).

Koul, Fisher and Shaw (2011) validated the TROFLEI in a study with a sample of 1,027 high-school students from 30 classes in New Zealand. Differences in actual and preferred scores of TROFLEI confirmed that students participating in the study preferred better learning environments. It was found that female students generally perceived their technology-related learning environment more positively than males. Statistically significant associations were found between the scales of TROFLEI and three affective outcome scales.

Welch et al. (2012) established the cross-cultural validity and reliability of the TROFLEI in both Turkey and the USA with a sample of approximately 980 grades 9–12 students in Turkey and 130 grades 9–12 students in the USA. The study showed that the TROFLEI can be used with both Turkish and US high-school students. The researchers also highlighted that the psychometric properties should be examined further in different populations, such as middle-school students (grades 6–8).

2.3.2.9 Constructivist-Oriented Learning Environment Survey (COLES)

The Constructivist-Oriented Learning Environment Survey (COLES) was developed to provide teachers with feedback information about their classroom environments based on their students' perceptions. The intent is to facilitate teachers to reflect on their teaching practices which, in turn, can guide the implementation of strategies to improve their learning environments. Six scales from the WIHIC (Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Cooperation and Equity), two scales from the TROFLEI (Differentiation and Young Adult Ethos), one scale from CLES (Personal Relevance) and two new scales related to assessment (Formative Assessment and Assessment Criteria) are included in the COLES. The COLES has a total of 88 items in 11 scales and it uses a five-point frequency scale with response options of Almost Never, Seldom, Sometimes, Often and Almost Always. Students are required to indicate their responses to both the actual and preferred forms of the COLES.

Aldridge, Fraser, Bell and Dorman (2012) reported that their study with a sample of 2043 Grade 11 and 12 students from 147 classes in 9 schools confirmed the validity and reliability of COLES. The Rasch model was used to convert data collected using a frequency response scale into interval data that are suitable for parametric analyses. Data analysis using the Rasch model showed that differences in the validity results (reliability, discriminate validity, and ability to differentiate between classrooms) between raw scores and Rasch scores were negligible.

2.3.2.10 Place-Based and Constructivist Environment Survey (PLACES)

Using participatory and conventional research methods, Zandvliet (2013) developed and validated an adapted version of the Place-Based and Constructivist Environment Survey (PLACES) called the SMILES for use in elementary place-based education programmes. The original version of PLACES has a total of seven scales (Zandvliet, 2012) drawn from four established learning environment inventories: the Environment Science Learning Inventory (ESLEI), the WIHIC, the SLEI and the Science Outdoor Learning Environment Instrument (SOLEI). The scales of Student Cohesion, Integration and Involvement were adapted from the ESLEI (Henderson &

Reid, 2000). The scales of Teacher Support and Cooperation were adapted from the WIHIC questionnaire. The scale of Open-Endedness was adapted from the SLEI and the final scale of Environment Interaction was adapted from the SOLEI (Orion et al., 1994).

The SMILES consists of 24 items and its simplified language facilitates reading by elementary students (adapted from the original PLACES instrument). It has three items for each of the eight scales of Relevance/Integration, Critical Voice, Student Negotiation, Group Cohesiveness, Student Involvement, Shared Control, Open Endedness and Environmental Interaction. It has a simplified frequency response scale which ranges from positive Almost Always (5), neutral Sometimes (3) to Almost Never (1).

The purpose of SMILES is to capture student perceptions of their wider experiences in localised place-based environment education settings that have an outdoor/experiential component and constructivist pedagogy. The instrument was administered to 169 students from Grades 4 through 7 at Bowen Island Community School in Canada. Each student responded to both an actual and a preferred version of the instrument. Students report on the ideal aspects of the learning environment that they would prefer in a given setting by using the preferred version of the instrument. Using the actual version of the instrument, students rate the environment that they have actually experienced over a period of several months.

Zandvliet (2013) found that students generally rated the actual learning environment less positively than they rated their ideal learning environment on several factors. These findings are consistent with past learning environment studies (Fraser, 1998b, 2012, 2014). Analyses confirmed the validity and reliability of the questionnaire in a range of classrooms, with the scales of the questionnaire supporting an ecological view of classrooms in which learning environment factors such as pedagogy and environmental interaction work together to create positive learning environments.

2.3.3 What Is Happening In this Class? (WIHIC)

Because I used numerous scales from the WIHIC in my study, this section presents a comprehensive review of the literature relevant to the WIHIC. As my study involved the use of a modified version of the WIHIC, I wanted to glean insights from previous research that was conducted with modified versions of the WIHIC.

The WIHIC assess seven of the most salient scales from a collection of existing learning environment instruments (Fraser, 1998a): Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation and Equity. The frequency response options are Almost Never, Seldom, Sometimes, Often, and Almost Always, which are scored 1–5, respectively.

There are several reasons for the choice of this instrument. First, the WIHIC maps a more comprehensive area of science learning environments than many of the other existing learning environment instruments because it combines relevant dimensions from other surveys (Fraser, 2002). Secondly, as the WIHIC is one of the most-frequently used classroom instruments around the world today, it has been validated in a number of countries and it has proven to be cross-culturally valid (Dorman, 2003). This is an advantage relative to some of the country-specific instruments that exist in the field. Thirdly, the instrument is reliable when measuring students' perceptions of important elements of their learning environment and has demonstrated predictive validity for both achievement in science and students' science-related attitudes (Fraser, 2012). Fourth, the 56 items in 7 scales make the instrument easy to use and economical in that it does not require too much time to administer.

By building on relevant dimensions from past learning environment questionnaires and incorporating other scales that measure particular aspects of constructivism and contemporary concerns, the WIHIC measures a wide range of dimensions that are important to the current situation in the classrooms (Dorman, 2003). A description of each scale in the WIHIC is presented in Table 2.2. Moos' (1979) dimensions of relationship, personal growth and system maintenance and change are encompassed by the WIHIC (see Table 2.2).

Another distinctive feature of the WIHIC is that it has different forms, one for the student to respond as an individual and the other for the student to respond based on the class as a whole (Fraser et al., 1996). Developed by Fraser, Fisher, and McRobbie (1996), the original WIHIC had 90 items in 9 scales. Through extensive analysis of responses from 355 junior high school science students, as well as detailed interviews, 54 items in seven different scales were found to be valid and reliable. More items were then added to make a total of 80 items and it was field tested to form the final version of the WIHIC.

Table 2.2 Scale Description for Each Scale of the WIHIC Questionnaire

WIHIC Scale	Description of Scale	Sample Item	Moos (1979) dimension
Student Cohesiveness	Extent to which students know, help and are supportive of one another.	In this class, I get help from other students.	Relationship
Teacher Support	Extent to which the teacher helps, befriends, and is interested in students.	The teacher takes a personal interest in me.	Relationship
Involvement	Extent to which students have attentive interest and participate in discussions.	I explain my ideas to other students.	Relationship
Investigation	Emphasis on the skills and processes of inquiry and their use in problem solving and investigation.	I carry out investigations to answer questions which puzzle me.	Personal growth
Task Orientation	Extent to which it is important to complete activities planned and to stay on the subject matter.	I know what I am trying to accomplish in this class	Personal growth
Cooperation	Extent to which students cooperate rather than compete with one another on learning tasks.	When I work in groups in this class, there is teamwork	Personal growth
Equity	Extent to which students are treated equally by the teacher.	I get to use the equipment as much as other students.	System Maintenance and change

Adapted from Aldridge, Fraser & Huang (1999)

The final version was field tested in Australia with 50 classes comprising a total of 1,081 students. It was also translated into Chinese and used in Taiwan with 50 classes comprising a total of 1,879 students (Aldridge & Fraser, 2000; Aldridge, Fraser, & Huang, 1999). These analyses led to a refined instrument with 56 items in seven scales. There are 8 items for each scale. The study supported the reliability and validity of both the English and Mandarin versions of the WIHIC. The a priori factor structure was confirmed with nearly all of the items loading on their own factor and on no other factor. Both the internal consistency for two units of analysis (α reliabilities greater than 0.8) and ability to differentiate between classrooms were found to be satisfactory.

Following that, the WIHIC was found to be valid and reliable for measuring classroom environments in numerous studies in the USA and Asia. The WIHIC was cross-nationally validated by Doman (2003) with a sample of 3,980 high-school students from Grade 8, 10 and 12 mathematics classes in Australia, the UK and Canada. In this study, Dorman reported that confirmatory factor analysis supported the WIHIC's seven-scale a priori structure. Another finding was that multi-sample analyses within structural equation modelling substantiated invariant factor structures for the three grouping variables of country, grade level and gender. This study therefore supported "the wide international applicability of the WIHIC as a valid measure of classroom psychosocial environment" (2008, p. 231).

In a second study, using both the actual and preferred forms of the WIHIC with a sample of 978 secondary-school students from Australia, Dorman (2008) further validated the WIHIC with multitrait–multimethod modelling. The results of confirmatory factor analysis indicated a good fit, model parsimony and model comparison (Dorman, 2008). This is consistent with many past studies which have shown that the WIHIC has strong factorial validity and internal consistency reliability for both its actual and preferred forms (Fraser, 2012, 2014).

2.3.4 Validity of WIHIC

Generally, research seems to indicate that the reliabilities of WIHIC scales (Cronbach's α coefficient) are usually above 0.70 at the student level and above 0.85 at the class level (MacLeod & Fraser, 2010). Regarding the degree to which an instrument is capable of distinguishing between different classes, the intra-class correlation coefficients for the WIHIC have been reported as being rather low, ranging roughly between 5% and 15% (den Brok et al., 2006b; Dorman, 2003).

Nonetheless, these values are similar to findings with respect to student views of climate and affective outcomes in school effectiveness research (Scheerens & Bosker, 1997); the majority of the variance in such variables has been reported to be around or below 10% at the class and teacher levels.

Exploratory and confirmatory factor analyses indicated that the items of the WIHIC usually have factor loadings of above 0.40 on their a priori scales and lower loadings on other scales. In addition, the factor structure has been shown to be invariant across grade levels, countries, cultures and gender (Dorman, 2003). This suggests the WIHIC's usefulness in studying multicultural and heterogeneous school populations. Average correlations between the scales of the WIHIC have been reported as being between 0.20 and 0.50, indicating that each of the seven scales measures distinct elements of the classroom environments despite the fact that they are partly overlapping.

Ogbuehi and Fraser (2007) used a modified version of the WIHIC with 22 middle-school mathematics classes in four inner-city schools in California to study the effectiveness of using innovative teaching strategies for enhancing the classroom environment and students' attitudes and conceptual development. The results from this study confirmed the ability of selected WIHIC scales to distinguish between different classes, as well as their sound factor structure, internal consistency reliability and discriminant validity.

A modified version of the WIHIC questionnaire was used by Allen and Fraser (2007) in their study of parent and student perceptions of classroom learning environment and student outcomes. Their data analyses for a sample of 520 Grade 4 and Grade 5 students aged 9–11 years from 22 classes in 3 schools and 120 of their parents in South Florida 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 the current reality, but effect sizes for actual–preferred differences were larger for parents than for students. Associations were found between some learning environment scales, especially Task Orientation, and student attitudes. Qualitative findings from this study suggested that students and parents were generally satisfied with the classroom environment, and that students would prefer more Investigation, while parents would prefer more Teacher Support.

Wolf and Fraser (2008) combined the WIHIC and a modified form of the TOSRA to create a questionnaire known as the Survey of Laboratory Practices (SLAP). The purpose of SLAP was to evaluate the use of inquiry teaching in science based on a sample of 1,434 students from 71 middle-school classes by comparing students' perceptions of inquiry and non-inquiry science classes. The data from this questionnaire were triangulated with data collected through interviews. Again, data analyses supported the WIHIC's factorial validity and internal consistency reliability for these middle-school students in New York. The finding also suggested that inquiry teaching promoted more student cohesiveness and was differentially effective for male and female students.

In another study, scales from the CLES and WIHIC were used to examine the effect of a teacher professional development programme which integrates technology into mathematics and science lessons. The sample size for this research was 759 students of seven mathematics/science teachers in a middle school in Florida. The results supported the validity and reliability of the learning environment scales chosen for assessing perceptions of the classroom environment among middle-school mathematics/science students in Miami-Dade County, Florida (Biggs, 2009).

The scales in WIHIC have also been used with TOSRA and the QTI to investigate associations between teacher–students interactions, students' perception of their classroom learning environment, student gender and student cultural background, and student outcomes. This modified version of the WIHIC was used to study 1,021 students in 32 science classes in seven co-educational private schools in Jammu, India. Data analyses supported the validity and reliability of each instrument. Multiple regression analyses showed that three scales of the WIHIC (Investigation, Task Orientation and Equity) and the QTI scale of Helping/Friendly were positively and significantly related to students' attitudes (Koul & Fisher, 2005).

In Korea, the WIHIC and QTI questionnaires were used to investigate classroom environment and teacher interpersonal behaviour in secondary science classes (Kim, Fisher & Fraser, 2000). The questionnaires were translated into the Korean language and then administered to 543 students in 12 different Korean schools to investigate associations between students' attitudes to science and their perceptions of the classroom environment. The cross-cultural validity of the WIHIC and QTI was supported. There were positive relationships between classroom environment or interpersonal teacher behaviour and students' attitudinal outcomes.

In Indonesia and Australia, Fraser, Aldridge and Adolphe (2010) cross-validated a modified version of the WIHIC, investigated differences between countries and genders in perceptions of the classroom environment, and examined associations between students' attitudes to science and their perceptions of classroom environment. A total of 1,161 students, 594 students from 18 classes in Indonesia and 567 students from 18 classes in Australia, confirmed the validity of this version of the WIHIC through principal components factor analysis with varimax rotation. Some differences between countries and genders in students' perceptions of their classroom environment were found through using a two-way MANOVA. Multiple regression and simple correlation analyses revealed positive associations between the classroom environment and student attitudes to science in both countries. Teacher Support and Involvement were found to be the strongest predictors of student attitudes to science in both Indonesia and Australia.

A primary-school version of the What Is Happening In this Class? (WIHIC–Primary) was used to determine students' preferred and actual views of their learning environments in a distance-education programme. The WIHIC–Primary was administered to the 1,077 learners by 31 teachers. This was the first learning environment study conducted at the primary level in South Africa. Feedback from this questionnaire was used to inform teaching practices for a 12-week intervention period. This study cross-validated an IsiZulu version of the WIHIC and supported the success of teachers' use of a learning environment questionnaire to guide improvements in classroom practices (Aldridge, Fraser & Ntuli, 2009).

Chua, Wong and Chen (2011) customised items from the original WIHIC to create a bilingual instrument, Chinese Language Classroom Environment Inventory (CLCEI), to investigate the Chinese Language classroom environment in Singapore.

Validation of the CLCEI showed that each of the six scales of the CLCEI had high internal consistency reliability and adequate discriminant validity. Analysis of data from 50 teachers and 1,460 Grade 9 students from 50 Chinese Language classes revealed that female students perceived the learning environment more positively than their male counterparts. Comparing actual and preferred perceptions for both teachers and students revealed that both teachers and students would like to have a more positive learning environment. Their findings showed that both teachers and students would like a learning environment in which there is a good amount of teacher and peer support and where students are actively involved in learning, are kept on task, cooperate with each other and feel that they are treated equally.

Taylor and Fraser (2013) cross-validated the WIHIC and an updated Revised Mathematics Anxiety Rating scale with a sample of 745 high-school students in 34 different mathematics classrooms in four high schools in Southern California. Factor analysis of the 56 WIHIC items replicated the strong factor structure reported in past research. Various statistical analyses showed that the WIHIC is a reliable instrument with a strong level of internal consistency and that it is valid for use in high-school mathematics classes in Southern California. Taylor and Fraser investigated the relationships between the learning environment and students' mathematics anxiety and differences between the sexes in their perceptions of learning environment and anxiety. Relative to males, females perceived a more positive classroom environment and more anxiety about mathematics evaluation, but less anxiety about mathematics learning. They also found some statistically significant associations between anxiety and learning environment scales for learning mathematics anxiety but not for mathematics evaluation anxiety.

Table 2.3 lists 27 studies (organised in terms of the country from which their sample was drawn) involving the WIHIC in various countries and in various languages. These studies have reported evidence to support the factorial validity and internal consistency reliability of the WIHIC. The majority of these studies also provided evidence of the ability of the WIHIC to differentiate between the perceptions of students in different classrooms. Details such as the size and nature of the sample, which specific student outcomes were included when investigating the relationship between the environment and student outcomes, and the unique contributions of each study are presented in this table.

In Table 2.3, the first four studies are examples of cross-national research 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 the use of WIHIC in English in Singapore by Chionh and Fraser (2009), Khoo and Fraser (2008), Chua, Wong and Chen (2011) and Peer and Fraser (in press), in India by Koul and Fisher (2005), in Australia by Dorman (2008), and in South Africa by Aldridge, Fraser and Ntuli (2009).

The 12th and 13th studies in Table 2.3 involved the use of the WIHIC in the Korean language and the Indonesian language, respectively, by Kim, Fisher and Fraser (2000) and Wahyudi and Treagust (2004). The next two studies involved the use of an Arabic translation of the WIHIC in the United Arab Emirates by MacLeod and Fraser (2010) and Afari, Aldridge, Fraser and Khine (2013). This is followed by a study in Spanish in Florida by Adamski, Fraser and Peiro (2013).

The next six studies listed in Table 2.3 involved the use of the WIHIC in the USA in four studies in California by den Brok, Fisher, Rickards and Bull (2006), Ogbuehi and Fraser (2007), Martin-Dunlop and Fraser (2008) and Taylor and Fraser (2013) and two studies in New York by Wolf and Fraser (2008) and Cohn and Fraser (2013). This is followed by four studies in Florida by Pickett and Fraser (2009), Allen and Fraser (2007), Robinson and Fraser (2013) and Helding and Fraser (2013).

The final study in Table 2.3 was conducted in Canada by Fraser and Raaflaub (2013). Every study in Table 2.3 has reported evidence of sound psychometric properties of the WIHIC, as well its wide international applicability in making unique contributions in various studies on classroom learning environments (see the last column of this table). The 27 studies presented in Table 2.3 are indeed testaments that “the WIHIC has achieved almost bandwagon status in the assessment of classroom environments” (Dorman, 2008, p. 181).

Table 2.3 Contributions of 27 Studies Involving WIHIC in Various Countries and in Various Languages

References	Country(ies)	Language(s)	Sample(s)	Associations with environment for	Unique contributions
Aldridge et al. (1999); Aldridge & Fraser (2000)	Australia Taiwan	English Mandarin	1,081 (Australian) and 1,879 (Taiwan) junior high	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, level and sexes.
Fraser et al. (2010a)	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 Attitudes Self-esteem	Differences between geography and mathematics classroom environments were smaller than between actual and preferred environments.
Khoo & Fraser (2008)	Singapore	English	250 working adults attending computer education courses	Satisfaction	Males perceived more trainer support and involvement but less equity.
Chua et al. (2011)	Singapore	English Chinese	50 teachers and 1,460 grade 9 students in 50 classes	NA	Developed bilingual instrument (English and Chinese) for investigating Chinese Language learning environment
Peer & Fraser (in press)	Singapore	English	1,081 primary science students in 55 classes	Attitudes	Grade-level, sex differences and stream differences, stream-by-sex and grade-by-stream interactions

(continued)

Table 2.3 (continued)

References	Country (ies)	Language(s)	Sample (s)	Associations with environment for	Unique contributions
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 et al. (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 practice.
Kim et al. (2000)	Korea	Korean	543 grade 8 science students in 12 schools	Attitudes	Korean translation Sex differences in WIHIC scores
Wahyudi & Treagust (2004)	Indonesia	Indonesian	1,400 lower-secondary science students in 16 schools	NA	Indonesian translation Urban students perceived greater cooperation and 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.

(continued)

Table 2.3 (continued)

References	Country(ies)	Language(s)	Sample (s)	Associations with environment for	Unique contributions
Adamski et al. (2013)	Florida	Spanish	223 Hispanic Grade 4–6 students	Attitude (Culture) Enjoyment Achievement	Spanish translation Influence of classroom environment and home environment on student outcomes
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 students in 27 classes	Attitude	Very large increases in learning environment scores for an innovative course
Ogbuehi & Fraser (2007)	California, USA	English	661 middle-school mathematics students	Two attitude scales	Used 3 WIHIC and 3 CLES scales Teaching strategies promoted task orientation.
Taylor & Fraser (2013)	California, USA	English	745 high-school students in 34 classes	Mathematics Anxiety	Sex differences in both learning environment perceptions and mathematics anxiety
Wolf & Fraser (2008)	New York, USA	English	1,434 middle-school science students in 71 classes	Attitudes Achievement	Inquiry-based laboratory activities promoted cohesiveness and were differentially effective for males and females
Cohn & Fraser (2013)	New York, USA	English	1,097 grade 7–8 students in 47 classes	Attitude	Learning environment scales used as process criteria in evaluating a teaching method using Student Response Systems

(continued)

Table 2.3 (continued)

References	Country (ies)	Language(s)	Sample (s)	Associations with environment for	Unique contributions
Allen & Fraser (2007)	Florida, USA	English Spanish	120 parents and 520 grade 4 and 5 students	Attitudes Achievement	Involved both parents and students Actual-preferred differences were larger for parents than students.
Pickett & Fraser (2009)	Florida, USA	English	573 grade 3–5 students	NA	Evaluated mentoring program in terms of changes in learning environment in teachers' classrooms
Robinson & Fraser (2013)	Florida, USA	English Spanish	78 parents and 172 kindergarten science students	Achievement Attitudes	Spanish translation Parents perceived a more favourable but preferred a less favourable environment than children.
Helding & Fraser (2013)	Florida, USA	English Spanish	924 students in 38 grade 8 and 10 science classes	Attitudes Achievement	Students of NBC teachers had more favourable classroom environment perceptions.
Fraser & Raaflaub (2013)	Ontario, Canada	English	1,173 Grade 7–12 students in 73 mathematics and science classes	Attitudes	Science students reported more positive learning environment perceptions and attitudes than mathematics students.

Adapted from Fraser (2012)

2.3.5 Research Applications Involving Classroom Environment Instruments

A student's perception of the learning environment of a classroom has been acknowledged as a mediating factor between characteristics of the learning environment and a student's learning (Stern et al., 1956). In the words of Fisher and Khine (2006, p. v), "To improve student achievement, improving the learning environment became a starting point of many reform movements". The study of learning environments has moved from descriptive studies of relationships between learning environment characteristics and student outcomes and studies of the impact of interventions on learning environments (curriculum reforms) to intervention studies and action research (Fisher & Khine, 2006).

One of the aims of my research was to evaluate the effectiveness of teachers' participation in a mathematics networked learning community in terms of students' classroom environments and attitudes to mathematics. Another aim was to investigate associations between students' perceptions of their classroom environment and their attitudes to mathematics. Therefore, this section reviews in detail the two past lines of research on which my research focused: evaluation of educational innovations; and associations between student outcomes and the environment. In addition, two other types of research with learning environment instruments are considered in somewhat less detail: determinants of classroom environments; and teachers' attempts to improve classroom environments.

2.3.5.1 Evaluation of Educational Innovations

Learning environment dimensions can be used as a source of process criteria in the evaluations of educational innovations. For example, in two studies in Singapore, classroom environment measures were used as dependent variables in evaluating computer-assisted learning by Teh and Fraser (1994) and computer application courses for adults by Khoo and Fraser (2008). When the Geography Classroom Environment Inventory was administered to a sample of 671 high school geography students in 24 classes in Singapore, Teh and Fraser (1994, 1995) found associations between classroom environment, achievement and attitudes. The experimental group of students using micro-PROLOG-based computer-assisted learning had much higher scores for achievement (3.5 standard deviations), attitudes (1.4 standard deviations) and classroom environment (1.0–1.9 standard deviations) than a control group. In the other study, a modified-version of the WIHIC was used to evaluate adult computer application courses with a sample of 250 adults in 23 classes in Singapore (Khoo & Fraser, 2008). Scales such as Teacher Support were renamed as Trainer Support. It was found that students of different sexes and ages had different perceptions of the effectiveness of the course, although students perceived their computing classes as being fairly high in Equity, Teacher Support, Task Orientation and Involvement. Males' perceptions of Trainer Support were independent of age, whereas older females had more positive perceptions than younger females. Males perceived significantly more Involvement and females perceived more Equity. Various analyses supported the factorial validity and reliability of the WIHIC when used with this adult sample in the Singapore context.

In an evaluation of an innovative science teacher development programme, Nix, Fraser and Ledbetter (2005) designed an innovative side–by–side response format for the CLES. The programme was evaluated in terms of the types of school classroom environments created by these teachers as perceived by their 445 students in 25 classes. Students' perceptions of the current class with the teacher who had experienced the professional development were compared with their perceptions of other classes at the same school taught by different teachers. Students of teachers who had experienced the professional development perceived their classrooms as having higher levels of the CLES scales of Personal Relevance and Uncertainty relative to the comparison classes.

The TROFLEI was used by Aldridge and Fraser (2008) to monitor and evaluate the success of an innovative new senior high school in promoting outcomes-focused education in Western Australia. The research involved 449 students in 2001, 626 students in 2002, 471 students in 2003 and 372 students in 2004. Changes in student perceptions of classroom environments, over a period of four years, were statistically significant and of moderate magnitude (with effect sizes ranging from 0.20 to 0.38 standard deviations) for seven of the ten TROFLEI scales. This supported the efficacy of the school's educational programmes. However, the degree of change in the learning environment differed for different learning areas depending upon the extent to which teachers were proactive in using outcomes-focused learning/teaching principles.

The WIHIC was administered to 1,434 middle-school science students in 71 classes in New York to evaluate the effectiveness of using inquiry-based laboratory activities in terms of learning environment, attitudes and achievement (Wolf & Fraser, 2008). This study supported the validity of the WIHIC and analyses of a sub-sample of students revealed that inquiry instruction promoted more Student Cohesiveness than non-inquiry instruction (effect size of one-third of a standard deviation). Inquiry-based instruction was also differentially effective for male and female students.

Pickett and Fraser (2009) drew on the field of learning environments to gauge the success of a two-year mentoring programme in science for beginning elementary-school teachers in terms of participants' classroom teaching behaviour as assessed by their school students' perceptions of their classroom learning environments. Seven beginning grade 3–5 teachers and 573 elementary-school students in south-eastern USA participated in this study. Student perceptions of the classroom learning environment were assessed as a pretest and a posttest using a modified version of the WIHIC. The use of MANOVA and effect sizes supported the efficacy of the mentoring programme in terms of some improvements in the classroom learning environment as well as in students' attitudes and achievements. Just like the evaluation of the mentoring programme, my study investigated whether the networked learning community had an impact on students' perceptions of their classroom learning environment as well as their attitudes to mathematics.

In Florida, Biggs (2009) used data from a questionnaire constructed from scales from the CLES, WIHIC and the Test Of Science-Related Attitudes (TOSRA) to evaluate the effectiveness of a teacher professional development program (Alliance+). The study involved a sample of 759 students of seven mathematics/science teachers. Four of the teachers had completed the Alliance+ project and three had not participated in the Alliance+ project. It was found that students' perceptions of three classroom learning environment scales (Teacher Support, Cooperation and Critical Voice) were more positive for the Alliance+ teachers than for the other group. However, the Alliance+ project was not effective in improving students' attitudes to science.

2.3.5.2 Associations between Student Outcomes and Environment

Historically, much past classroom environment research has focussed on the investigation of associations between students' cognitive and affective learning outcomes and their perceptions of psychosocial characteristics of their classrooms. A tabulation of 40 past studies in science education by Fraser (1994) shows that relationships between outcome measures and students' perceptions of their classroom environments have been replicated for a variety of cognitive and affective outcome measures, a variety of classroom environment instruments and a variety of samples which range across numerous countries and grade levels.

Below are some selected studies which revealed associations between student outcomes and students' perceptions of their classroom environment in various Asian countries, Australia and USA:

- In one of the pioneering learning environment studies in Singapore, Wong and Fraser (1996) established links between students' attitudes and scores on SLEI scales for a sample of 1592 Grade 10 chemistry students in 56 classes. In another early study in Singapore, Goh used both the MCI and the QTI with 1512 primary mathematics students in 39 classes to establish associations between the classroom environment and mathematics achievement and attitudes (Goh & Fraser, 1998, 2000). Quek et al. (2005) used both the SLEI and QTI to reveal links between classroom environment and student attitudes for a sample of 497 gifted and non-gifted secondary-school chemistry students. Khoo and Fraser (2008) established links between student satisfaction and dimensions of the WIHIC for a sample of 250 adults attending 23 computing classes. A comprehensive study using the actual and preferred form of the WIHIC established associations between the WIHIC scales and three student outcomes (examination results, attitudes and self-esteem) among a large sample of 2310 mathematics and geography students in 75 classes (Chionh & Fraser, 2009). The relationship between attitudes and classroom environment was established through the use of SLEI in both Singapore and Papua New Guinea (Waldrip & Wong, 1996).

- In Brunei Darussalam, Majeed et al. (2002) reported outcome–environment associations for satisfaction and scales of the MCI for a sample of 1565 Form

2 mathematics students in 81 classes. Khine and Fisher (2003) found associations between science attitudes and scales of both the WIHIC and QTI with a sample of 1188 Form 5 mathematics students in 54 classes. Based on a sample of 644 students in 35 chemistry classes from 23 government secondary schools, Riah and Fraser (1998) found that achievement and attitudes were related to the scales of the WIHIC, QTI and SLEI. Enjoyment of science lessons was found to be related to scales of a primary-school version of the QTI that had been translated into Standard Malay and used with 3104 students for 136 classes in 23 private schools (Scott & Fisher, 2004).

- In Indonesia, Margianti et al. (2001) reported that a study of 50 university classes comprising 2498 students revealed associations between the outcomes of achievement and attitudes and students' perceptions on an Indonesian-language version of the WIHIC. Fraser, Aldridge and Soerjaningsih (2010) used the Indonesian-language versions of the WIHIC and QTI with a sample of 422 university students in 12 classes to establish associations with student outcomes which included course achievement, leisure interest in computers, and attitude towards the Internet. In a study involving 1,161 students from Indonesia and Australia, Fraser, Aldridge and Adolphe (2010) found strong and positive associations between scales of the WIHIC (especially Teacher Support) and students' attitudes to science.

- In Korea, a study involving a sample of 440 students in 13 Grade 10 and Grade 11 science classes revealed associations between students' attitudes to science and the scales of a Korean-language version of the SLEI, CLES and QTI (Fraser & Lee, 2009; Lee et al., 2003). Likewise, a sample of 1083 students in 24 science classes was used to establish associations between student attitudes and a Korean-language version of the CLES (Kim, Fisher, & Fraser, 1999). Kim et al. (2000) also reported outcome–environment associations in their study involving the QTI and WIHIC with a sample of 543 students in 12 schools.

- In Taiwan, outcome–environment relationships have been found for student satisfaction in a study using Chinese-language version of both the WIHIC and

CLES with a sample of 1879 science students in 50 classes (Aldridge et al., 1999; Aldridge & Fraser, 2000; Aldridge et al., 2000).

- In Australia, associations with students' cognitive and affective outcomes have been established using the SLEI with a sample of 80 senior high-school chemistry classes (Fraser & McRobbie, 1995; McRobbie & Fraser, 1993) and 489 senior high-school biology students (Fisher et al., 1997). Dorman and Fraser (2009) used the TROFLEI to investigate classroom environment, antecedent variables (gender, grade level, home computer and Internet access) and student affective outcomes among 4146 high-school students in Western Australia and Tasmania. They found that improving classroom environment had the potential to improve student outcomes while antecedent variables did not have any significant direct effect on outcomes; and academic efficacy mediated the effect of several classroom environment dimensions on attitude to subject and attitude to computer use.

- In Florida, Allen and Fraser (2007) found associations between some learning environment dimensions (especially task orientation) and students outcomes (especially attitudes) in a study of parents' and students' perceptions of Grade 4 and 5 classroom learning environments using the WIHIC questionnaire. Peiro and Fraser (2009) found positive associations between students' attitudes and the classroom learning environment in a study using both an English and a translated Spanish version of CLES. Analyses also supported the validity of the instrument in both languages when used with a sample of 739 grade K–3 science students. In another study, Adamski et al. (2013) established relationships between students' perceptions of parental involvement in schooling, their Spanish classroom environment and student outcomes (attitudes and achievement). Using a modified Spanish version of the WIHIC and Test of Spanish-Related Attitudes with a sample of 223 Hispanic Grade 4–6 students in South Florida, the researchers found that the home environment was more influential than the classroom environment in terms of students' attitudes, but the classroom environment was more influential than the home environment in terms of achievement.

- In New York, Cohn and Fraser (2013) found that learning environment was positively and significantly associated with both attitudes and achievement. Data were gathered through the use of the How Do You Feel About This Class? questionnaire with a sample of 1,097 Grade 7 and 8 students in 47 classes in an evaluation of the use of Student Response System in classroom teaching.

While many studies of associations between learning environments and student outcomes involved science classes (Fraser, 2007), there have been some studies in mathematics classes on this aspect. For example, Ogbuehi and Fraser (2007) found associations between perceptions of classroom learning environment and students' attitudes to mathematics and conceptual development. This study was based on a sample of 661 middle-school students in California who responded to the CLES, WIHIC and TOMRA questionnaires. Webster and Fisher (2003) examined the relationship between learning environments and the student outcomes of achievement, career aspirations, attitudes toward mathematics and academic efficacy. Using the School-Level Environment Questionnaire (SLEQ) to collect data from a sample of 620 students and 4,645 students in 57 Australian secondary schools, they found that students' perceptions of the learning environment were associated with student outcomes.

Research that focused on at-risk mathematics students and their perceptions of the learning environment includes a study by Veldman and Sanford (1984) with a sample of 136 junior high mathematics and English classes in Texas. Their findings suggested that differences in classroom environment have more impact on achievement and behaviour among lower-ability students than for higher-ability students. In another study, Padron et al. (1999) reported that a more positive learning environment can help non-resilient students to improve their classroom behaviour. This study involved the use of MCI with 90 Grade 6 and Grade 8 classrooms from 16 inner-city middle schools.

A meta-analysis involving 734 correlations from 12 studies comprising 823 classes, eight subject areas, 17,805 students and four nations was conducted by Haertal et al. (1981). Their findings highlighted that learning posttest scores and regression-adjusted gains were consistently and strongly associated with cognitive and affective learning outcomes. Correlations were generally higher for samples of older students and in studies employing collectivities such as classes and school, in contrast to individual students, as the units of statistical analysis. In particular, classes perceived as having greater Cohesiveness, Satisfaction and Goal Direction and less Disorganisation and Friction were found consistently to have better achievement on a variety of outcome measures. This is supported by other meta-analyses synthesised by Fraser et al. (1987) which provided further evidence to support the link between educational environments and student outcomes.

2.3.5.3 Determinants of Classroom Environments

Classroom environment dimensions have been used as criterion variables in investigating the effect on classroom environment of factors such as class size, grade level, teacher personality, subject and the type of school (Fraser, 1994). For example, in Japan, Hirata and Sako (1998) studied differences between the classroom environment perceptions of normal students and at-risk students. In Singapore, interesting differences in classroom environment perceptions have been identified when comparing gifted and non-gifted students (Quek et al., 2005). Khine and Fisher (2003) found differences in students' classroom environment perceptions depending on whether the teacher was Asian or Western in a study in Brunei. In Indonesia, differences in classroom environment were found for university students for different subjects, namely, statistics and linear algebra (Margianti et al., 2001). Such differences have also been observed between computer science and management classes in Indonesia (Fraser, Aldridge, & Soerjaningsih, 2010).

The determinant of classroom environment that has been most widely researched in Asia is student gender. Based on within-class comparisons of students' perceptions, these studies revealed that females typically have more favourable views of their classroom learning environment than the males (Fraser, 2002). These studies were conducted in countries such as Brunei (Khine & Fisher, 2003; Riah & Fraser, 1998), Korea (Kim et al., 2000), Singapore (Chionh & Fraser, 2009; Goh & Fraser, 1998; Khoo & Fraser, 2008; Quek et al., 2005; Wong & Fraser, 1996) and Indonesia (Margianti et al., 2001).

Peer and Fraser (in press) investigated sex, grade-level and stream differences in learning environment perceptions and attitudes to science. They used ten scales from the WIHIC, CLES and TOSRA to collect data from 1,081 primary science students in 55 classes in Singapore. Their study showed that there were significant sex differences for Involvement, Teacher Support, Task Orientation and Cooperation; significant grade-level differences for Teacher Support, Task Orientation, Cooperation and Enjoyment; significant stream differences for Involvement, Cooperation and Personal Relevance; significant stream–by–sex interactions for Task Orientation and Enjoyment; significant grade–by–stream interactions for Investigation, Student Negotiation, Scientific Inquiry and Enjoyment; and no significant grade–by–sex or stream–by–sex–by–grade interaction for any dependent variable.

2.3.5.4 Teachers' Attempts to Improve Classroom Environments

Much research has been undertaken into educational environments, but more could be done to help teachers to improve the environments of their own classrooms or schools. Fraser and Fisher (1986) used the CES and a five-step procedure to demonstrate how feedback information based on student or teacher perceptions can serve as a basis for reflection of, discussion of, and systematic attempts to improve classroom environments. The five-step procedure included (1) assessment, (2) feedback, (3) reflection and discussion, (4) intervention, and (5) reassessment. Studies of this nature were conducted at numerous levels, including the early childhood level (Fisher, Fraser, & Bassett, 1995), primary level (Aldridge, Fraser & Ntuli, 2009; Fraser & Deer, 1983), secondary level (Aldridge, Fraser & Sebela, 2004; Thorp, Burden, & Fraser, 1994) and higher-education level (Yarrow & Millwater, 1995; Yarrow, Millwater, & Fraser, 1997).

In a study in Western Australia, both the preferred and actual forms of the COLES were administered to a sample of 2043 Grade 11 and Grade 12 students from 147 classes in 9 schools. In addition to information obtained from COLES, reflective journals, written feedback, forum discussions and teacher interviews were used to provide feedback for improving classroom environments. A pretest was administered at the start of the study. The posttest was administered again after six weeks of intervention strategies aimed at reducing the actual–preferred discrepancies. Data analysis supported the validity and reliability of the COLES in this study. A circular profile was used as a means of providing each teacher with a comparison of mean actual and preferred responses for his/her class (Aldridge, Fraser, Bell & Dorman, 2012).

2.3.6 Cross-National Studies

Fraser (2007) advocated that educational research that crosses national boundaries offers much promise for generating deeper insights as there is greater variation in variables of interest, such as teaching methods and student attitudes. The taken-for-granted assumptions of educational practices of one country can be uncovered when exposed to research which involves more than one country. The following paragraphs discuss some studies that involved bringing together data from different countries in learning environment research.

A cross-national study of science laboratory classroom environments in a number of schools in six countries (Australia, USA, Canada, England, Israel and Nigeria) was carried by Fraser, Giddings and McRobbie (1995). The sample involved 3,727 students from 198 classes in schools and 1,720 students from 71 university classes. This six-country study showed that science laboratory classes around the world are strongly dominated by closed-ended activities. The study also revealed that the females had more favourable perceptions of their learning environment than males. There were statistically significant associations between attitudinal outcomes and laboratory environment dimensions.

In another cross-national study, the QTI was administered to students and teachers from a sample of 20 classes from 10 schools in each of Australia and Singapore (Fisher, Goh, Wong & Richards, 1997). Compared with the Singapore sample, Australian teachers were perceived as giving more responsibility and freedom to their students. Teachers in Singapore were perceived as being stricter than their Australian counterparts.

Dorman (2003) carried out a cross-national study to validate the WIHIC questionnaire with 3,980 high-school mathematics students from Australia, the UK and Canada. He used multi-sample analyses within structural equation modelling to substantiate an invariant factor structure for three grouping variables: country, grade level and student gender. This study supported the widespread international applicability of the WIHIC as a valid measure of classroom psychosocial environment.

Fraser, Aldridge and Adolphe (2010) carried out a cross-national study of classroom environments in Australia and Indonesia with a sample of 1,161 students (594 students from 18 classes in Indonesia and 567 students from 18 classes in Australia). Analysis of data collected with a modified version of the WIHIC showed some differences between countries and between sexes in students' perceptions of their classroom environment. For the scales on Involvement and Investigation, Indonesian students perceived their learning environments significantly more positively than did the Australian students. However, Australian students had significantly more positive perceptions of their classroom environment than their Indonesian counterparts for the scales on Task Orientation and Equity. A statistically significant country–by–sex interaction was identified for one learning environment scale, namely, Student Cohesiveness.

2.4 ATTITUDES TO MATHEMATICS

Research on attitudes has a long history in mathematics education and it has its origin in the field of social psychology (Allport, 1935). In the field of mathematics education, research on attitudes has been motivated by the belief that attitudes play a crucial role in learning mathematics (Neale, 1969). Subscribing to this belief, I have used changes in attitudes to mathematics as an indicator in evaluating the effectiveness of teachers' participation in a mathematics networked learning community.

A literature review on attitudes towards mathematics and the development of instruments to assess attitudes is therefore presented in this section. Section 2.4.1 gives an overview of attitudes and some definitions of attitudes that are expounded in the literature. Section 2.4.2 discusses attitudes in relation to mathematics learning, while Section 2.4.3 reviews some past studies involving the evaluation of attitudes.

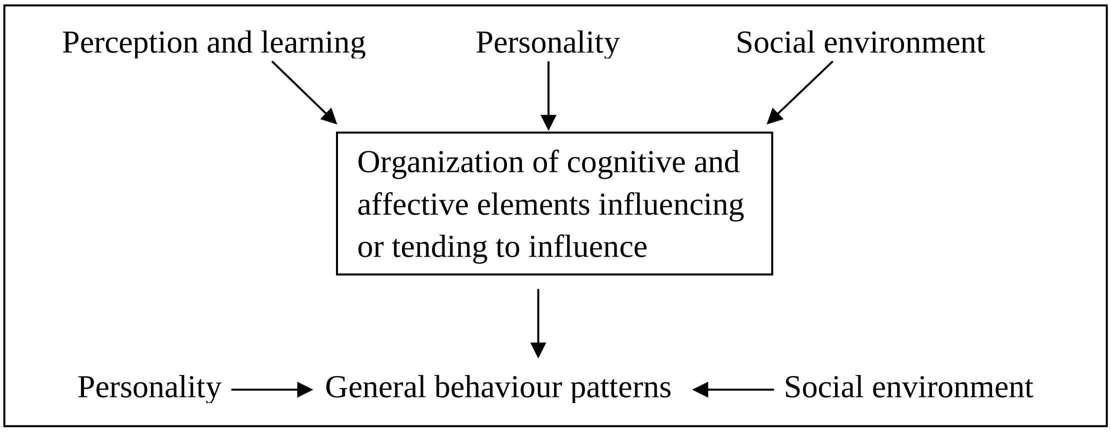
2.4.1 Some Definitions of Attitudes

Attitude is a concept that was originated in the early part of the 20th century and has been used in many different contexts (Koballa, 1988). Allport (1935) described attitude as a mental and neural state of readiness, organised through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related. Bogardus (1931) defined attitude as a tendency to act towards or against some environmental factor which therefore becomes a positive or negative value. A positive attitude towards mathematics indicates a positive emotional disposition towards the subject, whereas a negative attitude towards mathematics reflects a negative emotional disposition towards the subject (Zan & Martino, 2007). When it refers to an emotion, a positive attitude usually means 'perceived as pleasurable'.

Eshun (2004) defines an attitude towards mathematics as a disposition towards an aspect of mathematics that has been acquired by an individual through his or her beliefs and experiences but which could be changed. He argued that emotional dispositions have an impact on an individual's behaviour because one is likely to achieve better in a subject that one enjoys. For this reason, positive attitudes towards mathematics are therefore desirable because they can influence one's willingness to learn and also the benefits that one can derive from mathematics instruction.

Despite the many definitions of attitude, there is a common characteristic that prevails in these definitions. Attitudes have three components: a knowledge component (cognitive), a feeling component (affective) and an action-tendency component (conative) (Gauld & Hukins, 1980; Johnstone & Reid, 1981). Johnstone and Reid (1981, p. 206) view attitudes as aspects of learning and suggest that attitudes are 'attempts at solution'. They provide a pictorial representation of the possible relationship between the three components and their relationship to other influences as shown in Figure 2.1 below. This figure illustrates the influence of the cognitive and affective domains on learners' readiness to respond to outcomes. It also highlights the circumstances in which attitudes affect behaviour, which also might be modified by personality and social environment.

Given the complex nature of 'attitude' and its numerous definitions suggested by psychologists, in the following section below, I anchor discussions of attitudes based



Based on Johnstone & Reid (1981, p. 207)

Figure 2.1. Relationships between the Cognitive, Affective and Conative Components and Other Influences

the Singapore Mathematics Curriculum Framework. According to the Singapore Mathematics Curriculum Framework (MOE, 2007, p. 12), attitudes refer to the affective aspects of mathematics learning, such as beliefs about mathematics and its usefulness as well as interest and enjoyment in learning mathematics, appreciation of the beauty and power of mathematics, confidence in using mathematics and perseverance in solving a problem. The curriculum document emphasises the importance of inculcating positive attitudes towards mathematics. Reflecting on Kulm's (1980) suggestion that "it is probably not possible to offer a definition of attitude toward mathematics that would be suitable for all situations, and even if one were agreed on, it would probably be too general to be useful" (p. 358), I have defined attitudes as enjoyment in learning mathematics for the purpose of this study.

2.4.2 Attitudes and Mathematics Learning

Fraser (2001) highlighted that teachers have a great influence on students and need to be aware that the learning environment that they create for students can influence their attitudes towards the subject matter. In the same vein, Dossey (1992) regards teachers as playing an important role in shaping students' attitudes towards mathematics. The emotional and affective feelings that students bring to the classroom regarding the subject are crucial components of the learning environment. When the mathematics classroom is experienced as an uncomfortable and alien place by many students, it is a dysfunctional background for learning (Boaler, 2002). This relationship between attitudes and mathematics learning is mutually reciprocal, in that attitudes affect achievement and achievement in turn affects attitudes (Neale, 1969).

Bernstein (1964) asserted that, if certain feelings are experienced for a time, they will lead to a particular self-image that influences a person's expectation of future performance and actual performance. Nicolaidou and Philippou (2003) also contended that negative attitudes are the result of frequent and repeated failures or problems when dealing with mathematical tasks and that these negative attitudes can become relatively permanent. They showed significant correlations between attitudes and performance, with those students having positive attitudes achieving better. The results of a study of secondary students' attitudes towards mathematics in nine countries by Sanchez et al. (2004) showed that those with better academic performance have more positive attitudes regarding mathematics than those with poorer academic performance. Georgiou et al. (2007) showed that high achievement could serve to predict a positive attitude towards mathematics, but that such an attitude could not predict stronger achievement. They emphasized the role of teachers and schools in changing attitudes and argued that achievement in mathematics could be improved by better teaching methods, more motivated teachers or better coursebooks, which has as its corollary the improvement of attitudes towards mathematics.

Educators such as Goldin (1998) regard "the affective system of representation as the most fundamental to understanding the structure of mathematical ability in students and adults" (p. 155). This means that, if experiences in the mathematics classroom evoke positive emotions, then the learning is stronger and the positive memories stored increase the accessibility of a particular problem-solving strategy in the future. A negative attitude to mathematics could considerably reduce a person's willingness to persist with a problem. Consequently, students with positive attitudes towards mathematics tend to perform better than students with negative attitudes towards mathematics.

A study by Brown and Abell (1965) showed that the correlation between pupil attitudes towards a subject and achievement in that subject was higher for arithmetic than for spelling, reading or language. Antonnen (1969) reported that there is a strong positive correlation between attitude to mathematics and mathematical achievement. Maat and Zakaria (2010) and Vaughan (2002) identified a significant relationship between the learning environment and attitude towards mathematics. Students with more favourable perceptions of the learning environment and more positive perceptions of their teachers have more positive attitudes towards mathematics.

2.4.3 Evaluation of Student Attitudes

In general, attitudes are grounded in experience, are seen as either positive or negative and are directed towards something, such as mathematics in this case (McLeod, 1992). Although definitions of attitude vary, they generally include the idea that attitudes are learnt, manifest themselves in one's response to the object or situation concerned, and can be evaluated (Way & Relich, 1993). Mueller (1986) proposed that, because attitudes cannot be observed or measured directly, their existence must be inferred from their consequences.

Several aspects of school context, such as teacher support, student–to–student interaction and expectations of teachers were shown by Akey (2006) to be significantly related to student attitudes. In his study, Akey concluded that, in class environments where teachers were seen as supportive, student feelings of control and confidence in their ability to succeed were promoted. The way in which students perceived teacher characteristics affected their attitudes towards mathematics (Maat & Zakaria, 2010). Their findings were consistent with those of Vaughan (2002) who also identified a significant relationship between the learning environment and attitudes towards mathematics. Overall, more positive perceptions of the learning environment and of their teachers by the students were associated with more positive attitudes towards mathematics. Hemmings and Kay (2010) also found that students had more positive attitudes towards mathematics when they perceived that the teacher was supportive, and that effort was positively and significantly related to attitudes to mathematics.

A student's observed behaviour would seem to be an important indicator of his/her attitudes. However, Brown and Abel (1965) found that observations by teachers were inadequate for assessing their students' attitudes towards mathematics.

Subscribing to this finding, I decided to use a questionnaire to assess students' attitudes to mathematics in my study.

The Trends in International Mathematics and Science Study 2011 (TIMSS, 2011) reported that, within countries, students with more positive attitudes towards mathematics have substantially higher achievement, which is consistent with previous research (Mullis et al., 2012). Based on the notion that students' motivation to learn can be affected by whether they find the subject enjoyable and valuable, and their self-confidence in learning the subject, TIMSS (2011) included scales to assess three motivational constructs: intrinsic value (interest), utility value, and ability beliefs. For all three scales, students respond by circling one of these four options: Agree a lot, Agree a little, Disagree a little and Disagree a lot.

The Students Like Learning Mathematics scale was developed to measure students' intrinsic motivation such as interest and liking of learning mathematics. Students are scored according to the degree of their agreement with five statements such as "I enjoy learning mathematics", "Mathematics is boring" (reverse coded) and "I learn many interesting things in mathematics." The TIMSS Students Value Mathematics scale assesses intrinsic motivation with six items about students' attitudes, the importance and usefulness of mathematics. Examples of items are "I need to do well in mathematics to get into the university of my choice" and "I need to do well in mathematics to get the job I want." The TIMSS Confidence in Mathematics scale assesses students' self-confidence or self-concept in their ability to learn mathematics. The seven items include "Mathematics is harder for me than for many of my classmates" (reverse coded) and "My teacher tells me I am good at mathematics".

The Test of Science-Related Attitudes (TOSRA) has been found to be "useful and easy to use for measuring and monitoring progress of science-related attitudes of individual students or whole classes of students" (Fraser, Aldridge, & Adolphe, 2010, p. 557). The TOSRA was developed by Fraser (1978, 1981) to measure seven distinct science-related attitudes among high school students based on Klopfer's (1971) categories for the affective domain in science education. The seven scales of TOSRA are 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 has 10 items, making a total of 70 items in the TOSRA.

The Enjoyment of Science Lessons scale from TOSRA was used by Riah and Fraser (1998) to assess students' attitudes among a sample of 644 chemistry students from 35 classes in 23 government secondary schools in Brunei Darussalam. Statistical analyses of their data supported the validity and reliability of the TOSRA for use within this context. Wolf and Fraser (2008) also used the same single TOSRA scale to assess students' attitudes among 1,434 students in 71 classes in New York. Principal axis factoring with oblique rotation revealed that every attitude item had a factor loading above 0.30, therefore supporting the factorial validity of the attitudinal scale. Values of the Cronbach alpha coefficient also supported its internal consistency reliability.

A modified version of the TOSRA, called the Questionnaire on Chemistry-Related Attitudes (QOCRA), was designed by Wong and Fraser (1996) to assess students' attitudes towards chemistry in laboratory classrooms in Singapore. In the QOCRA, the word 'science' in TOSRA was replaced with 'chemistry' and likewise the word 'test' was replaced with the word 'questionnaire'. However, the original meaning of the sentences remained the same. The sample consisted of 1,592 final-year secondary (grade 10) school chemistry students in 56 intact classes in 28 randomly-selected coeducational government schools in Singapore. Statistical analyses also indicated that the QOCRA was valid and reliable for use in that context. Significant associations were also found between the nature of the chemistry laboratory classroom environment and the students' attitudinal outcomes. Subsequently, Quek, Wong and Fraser (2005) successfully used the QOCRA with a sample of 497 grade 10 students from three independent schools in Singapore. QOCRA was again found to be valid and reliable in this study.

The original version of the TOSRA was used by Fraser, Aldridge and Adolphe (2010) to assess students' attitudes to science in two culturally-different countries, namely, Australia and Indonesia. The sample comprised 1,161 students (594 students from 18 classes in Indonesia and 567 students from 18 classes in Australia). The TOSRA was translated into Indonesian for use with the Indonesian students. This study led to the acceptance of a revised version of TOSRA comprising 20 items based on principal components factor analysis followed by varimax rotation. The a priori factor structure of the revised version of the TOSRA was replicated in both countries, with a factor loading of at least 0.30 on their a priori scale and no other scale for nearly all items. MANOVA revealed that there were a few differences between Australian and Indonesian students' perceptions of their classroom environments and 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.

The TOSRA was modified to form the Test of Mathematics-Related Attitudes (TOMRA) by Spinner and Fraser (2005) to assess students' attitudes towards mathematics. For example, "Science lessons are fun" was changed to "Mathematics lessons are fun." Three of the original TOSRA scales were used with six items in each scale. The scales chosen were Normality of Mathematicians, Adoption of Mathematical Attitudes and Enjoyment of Mathematics Lessons. In this study involving two groups of fifth-grade students over an academic year, Spinner and Fraser (2005) found that students in the innovative mathematics programme experienced more favourable changes in terms of mathematics concept development and attitudes to mathematics.

Ogbuehi and Fraser (2007) used the TOMRA with a sample of 661 students from 22 classrooms in four inner-city schools in California to examine associations between perceptions of classroom learning environment and students' attitudes to mathematics and conceptual development. Their study suggested that more positive student attitudes were associated with more emphasis on the aspects of constructivism as assessed by the CLES, especially Personal Relevance and Student Control, and on dimensions assessed by the WIHIC, especially Involvement and Task Orientation. Drawing on these studies which had used TOSRA to investigate attitudes toward mathematics, I adapted eight items from the scale of Enjoyment of Mathematics Lessons from the TOSRA to assess enjoyment of mathematics.

In a study which involved a sample of 1,173 students Grade 7–12 students in 73 mathematics and sciences classes in Ontario in which laptop computers were used, Fraser and Raaflaub (2013) found associations between the learning environment and student attitudes. Their findings showed that differences between the actual and preferred classroom environments were large and statistically significant; females held more favourable learning environment perceptions but males reported more positive attitudes. Relative to mathematics students, science students reported more positive learning environment perceptions and attitudes. This finding could be an indication that there might be an association (although it was weaker for Science) between learning environment and attitudes to mathematics.

Sebela, Fraser and Aldridge (2004) used the Constructivist Learning Environment Survey (CLES) and an attitude scale to assess learners' perceptions of the constructivist learning environment and their attitudes towards their mathematics classrooms. The instruments were administered to 1864 learners in 34 intermediate (Grades 4–6) and senior (Grades 7–9) classes in South Africa. Simple correlation and multiple regression analyses were conducted to investigate associations between learners' attitudes towards their mathematics class and their perceptions of the learning environment. Student attitudes were found to be associated with more emphasis on all four CLES scales used. Two scales, Uncertainty and Student Negotiation, were found to contribute most to variance in student attitudes in mathematics classes in South Africa when the other CLES scales were mutually controlled.

2.5 GAPS IN THE LITERATURE

From this extensive review of literature from the fields of networked learning communities and learning environment, there appear to be mainly two gaps in the literature to be addressed in my study. How these gaps in the literature were addressed in my study are discussed in detail under Section 5.4 (Significance and Implications.

Based on the limited evidence on the impact of networked learning community as discussed in Section 2.2.4, there has been no previous study of learning environment created by teachers in learning communities and networks. Because classroom instruction is at the core of student learning and students' day-to-day classroom activities are likely to have a considerable impact on their mathematics learning, it is essential to consider the learning environment of the classroom itself. Therefore, my study filled a gap in the literature by providing empirical evidence about the impact of teachers' participation in networked learning community in terms of pre–post changes in their classroom learning environments and their students' attitudes to mathematics.

Learning environment dimensions have been used in the evaluations of educational innovations in many countries, including Singapore (see Section 2.3.5.1). However, no study has been undertaken into teachers' networked learning communities that involved students' perceptions of their mathematics classroom learning environments and attitudes to mathematics. Hence, the second gap which my study addressed is expanding the knowledge base in the learning environment research that has used classroom environment assessments as process criteria of effectiveness in evaluating educational innovations.

2.6 CHAPTER SUMMARY

The main objective of my study was to evaluate the effectiveness of teachers' participation in a mathematics networked learning community, which is a recent initiative in Singapore for promoting the professional learning of teachers across schools. Premised on the belief that changes in classroom behaviours are strong indicators of the effectiveness of professional development programmes, learning environment criteria therefore were used to assess the effectiveness of teachers' professional learning in a networked learning community. My study therefore focused on using modified versions of the WIHIC and TOMRA in evaluating changes in students' behaviour and attitudes to mathematics. To this end, three main areas of literature were reviewed in the current chapter: networked learning communities (Section 2.2), learning environment (Section 2.3) and attitudes to mathematics (Section 2.4).

Section 2.2.1 provided an overview of teachers' professional development in general, as well as the context in Singapore. Definitions of learning community were discussed in Section 2.2.2 to provide a transition into Section 2.2.3, which elaborated the concept of networked learning. Collaboration among teachers was also covered as this is a critical success factor in networked learning. Section 2.2.4 reviewed literature about the effect of networked learning on students' learning. Findings from some studies show that networks can be an effective vehicle for improving students' learning, while some studies reported that teachers' engagement in networked learning did not have any impact on teaching and classroom practices.

My study required an instrument for evaluating the effectiveness of teachers' participation in a mathematics networked learning community. Drawing on the consistent research findings of a link between a favourable learning environment and students' achievements and positive attitudes (Fraser, 1998a), learning environment criteria were employed to assess the effectiveness of teachers' professional learning in a networked learning community. Therefore, Section 2.3.1 reviewed the historical background of the field of learning environment and Section 2.3.2 reviewed 11 specific classroom environment questionnaires. Because the instrument used in my research was derived from WIHIC, Section 2.3.3 was devoted to the development of the WIHIC, its use in various studies and its proven validity and robustness in past research. Section 2.3.4 discussed the validity of the modified WIHIC in numerous different studies conducted by different researchers in different locations and contexts. Based on some important lines of past research in learning environments as identified by Fraser (2002), Section 2.3.5 focused on the evaluation of innovative educational programmes and the investigations of outcome–environment associations, which were reviewed in greater detail as they are of central relevance to my study. Two other lines of past research were also briefly discussed, namely, determinants of classroom environments and teachers' attempts to improve classroom environments.

Attitude to mathematics is another indicator that was used to measure the effectiveness of teachers' engagement in networked learning. Some definitions of attitude were discussed in Section 2.4.1 to provide an understanding of why I defined attitudes as enjoyment in learning mathematics for the purpose of this study. Section 2.4.2 focused on the influence of attitudes on mathematics learning, while Section 2.4.3 presented some studies in which attitudes were successfully evaluated using modified versions of TOSRA.

Chapter 3

METHODOLOGY

3.1 INTRODUCTION

The credibility of research depends not only on the validity and reliability of the instruments used, but also on the research methods employed. This chapter is written through the lens of the research methodology which underpins the design process for carrying out my study, data collection, data analysis and interpretation of findings to answer the research questions.

While Chapter 2 presented a review of literature relevant to my study, this chapter describes the methods used in investigating my research questions under these sections:

- Objectives and research questions (Section 3.2)
- Design of the study (Section 3.3)
- Instruments used (Section 3.4)
- Data sources (Section 3.5)
- Data collection (Section 3.6)
- Data analysis (Section 3.7)
- Summary (Section 3.8).

The primary goal of my study was to determine the effectiveness of a new professional development initiative, networked learning community, in terms of students' classroom learning environment perceptions and attitudes to mathematics through the use of a questionnaire. Networked learning community was adopted in Singapore in 2010 as a result of an internal review of professional development which revealed that the many workshops and courses provided for teachers had not led to changes in classroom practices. Because networked learning community as a form of professional development for mathematics teachers is a new initiative in Singapore, I embarked on this study to understand the effectiveness of teachers' participation in networked learning community and its impact on classroom practice as assessed in terms of changes in students' perception of classroom learning environment and attitudes to mathematics.

3.2 OBJECTIVES AND RESEARCH QUESTIONS

This section recapitulates the objectives of my study and the research questions. The main purpose of this research was to employ a learning environment framework to evaluate the effectiveness of teachers' participation in a networked learning community in terms of the learning environments created by these teachers in their mathematics classrooms in their respective schools, as well as their students' attitudes. Hence the main foci of this study were to:

1. ascertain if a questionnaire assessing classroom learning environment and attitudes to mathematics is valid when used with Primary 5 mathematics students in Singapore
2. investigate associations between students' perceptions of their classroom environment and their attitudes to mathematics
3. evaluate the effectiveness of teachers' participation in a mathematics networked learning community in terms of their students':
    a) perceptions of classroom learning environment
    b) attitudes to mathematics

After reviewing literature on the various questionnaires available, I chose three scales from the What Is Happening In this Class? (WIHIC, Fraser, Fisher & McRobbie, 1996) to measure students' perceptions of their classroom environment. Cooperation, Teacher Support and Involvement are the three scales chosen because they best describe the expected classroom practices as a result of the professional learning of teachers in the networked learning community. Another scale of Problem Solving was constructed to reflect the level of engagement in mathematics in the network and in the teachers' respective classrooms. I also extracted eight items from the Test of Science-Related Attitudes (TOSRA, Fraser, 1978) to form the Enjoyment scale to measure students' attitudes towards mathematics. These five scales form the Mathematics Classroom Environment and Attitude (MCEA) Questionnaire. Before the questionnaire could be used for answering the other research questions in the study, this instrument had to be validated to ensure that it actually measures what it sets out to measure and whether scores from it can be interpreted consistently across different situations. Reliability is a critical consideration for the choice of the instrument as I needed to compare data from two different groups of students, the experimental group and a comparison group, in terms of the pre–post changes in students' perceptions of their classroom learning environment and their attitudes to mathematics. This therefore involved answering the first research question.

Research Question 1:

Are the learning environment scales based on the WIHIC and a newly-constructed scale and an attitude scale based on TOSRA valid and reliable when used with a sample of primary-school mathematics students in Singapore?

After validating the questionnaire, the second research question was framed to examine whether relationships exist between students' perceptions of the classroom learning environment and their attitudes to mathematics.

Research Question 2:

Are there associations between each of the four learning environment scales and a scale which measures students' enjoyment of mathematics?

Finally, the third research question seeks to investigate the effectiveness of teachers' participation in mathematics networked learning community.

Research Question 3:

Does teachers' participation in a mathematics networked learning community make a difference in their classroom teaching in terms of their students':

a) *perceptions of classroom learning environment*

b) *attitudes to mathematics?*

3.3 DESIGN OF THE STUDY

A pretest–posttest quasi-experimental design was used to compare the changes in classroom environment and attitudes of those classes whose teachers participated in networked learning community with those classes whose teachers were not in networked learning community. This design was selected because there wasn't a random assigning of students and the variables within and among the classrooms could not be controlled (Shulman, 1997). Convenience sampling was therefore used because the class composition was determined by the participating teachers' schools and not by the researcher (Punch, 1998).

There was no control over the teaching methods used by teachers in their classrooms. The only variable controlled by the researcher was the professional learning which the five teachers in the experimental group experienced in the networked learning community. Although there were no specific instructions that these five teachers must teach differently, it was hypothesised that the teaching strategies learnt as elaborated in Section 1.2.2.1 and the exchange of instructional strategies, especially Cooperative Learning Strategies, with fellow educators in the networked learning community would have some impact on their classroom practice. This change in classroom practice was measured in terms of their students' perceptions of classroom learning environment and attitudes to mathematics before and after the teachers' participation in the networked learning community. The five teachers in the comparison group were left to teach as they normally would.

3.4 INSTRUMENTS USED

Numerous instruments have been extensively validated to assess and investigate classroom learning environments and student attitudes. Some of these instruments were reviewed in Chapter 2. After reviewing various instruments in the literature and in consultation with my research supervisor, I selected the WIHIC and the TOSRA as a basis for developing the MCEA questionnaire.

The instrument (MCEA questionnaire) used in this study to assess students' perceptions of their learning environment and their attitudes includes scales from existing and widely-used questionnaires. These scales were chosen for their relevance in answering my research questions. From the 56-item, 7-scale version of the WIHIC, I extracted three scales (Cooperation, Teacher Support and Involvement) for my instrument because they involve mathematics discussions in class and students' active participation in the learning. The four WIHIC scales that were excluded from my study were Student Cohesiveness, Investigation, Task Orientation and Equity. These scales were omitted because they do not assess constructs that were highly relevant to my study. The WIHIC was previously discussed in Section 2.3.3 and is again discussed in Section 3.3.1.

For a more comprehensive assessment of students' perceptions of the learning environment in their mathematics classrooms, a new learning environment scale called Problem Solving was created by the researcher. The Problem Solving scale attempts to assess a construct that is peculiar to the processes in which students are involved during mathematical problem solving. This is also aligned with the emphasis in the Singapore Mathematics Framework and with the primary goal of school mathematics in Singapore being mathematical problem solving.

To monitor changes in attitudes towards mathematics, items that were more relevant to my study were selected from the Test of Science-Related Attitudes (TOSRA; Fraser, 1981) to form the Enjoyment scale in the MCEA questionnaire. The TOSRA was reviewed previously in Section 2.4.3 and is considered again in more details in Section 3.4.2.

3.4.1 What Is Happening In this Class? (WIHIC) and Problem Solving Scale

The WIHIC, developed by Fraser, Fisher and McRobbie (1996), measures a wide range of dimensions that are important in daily situations in classrooms. Designed to bring parsimony in the field of learning environment research (Dorman, 2003), the WIHIC is worded so as to elicit a student's perceptions of his/her individual role within the classroom, as opposed to the student's perceptions of the class as a whole. Personal forms of classroom environment instruments are concordant with a constructivist theory of learning (von Glasersfeld, 1989).

Besides the items giving a clear picture of what goes on in the classroom, the wording of the items is easily understood by students. Typically, students are comfortable with the items as they do not directly assess their performance, personality or character. The WIHIC has been used in a multitude of previous studies around the world which have supported its factorial validity and internal consistency reliability in different countries and for different age groups. The contributions of studies involving WIHIC in various countries and in various languages were presented in Table 2.3 in Chapter 2. Table 3.1 below illustrates that the WIHIC has shown sound factorial validity and internal consistency reliability in numerous studies in different countries and grade levels. It also shows the numerical range of internal consistency reliability coefficients for different WIHIC scales.

Table 3.1 Internal Consistency Reliability for WIHIC Scales in Different Countries and Grade Levels

Country (ies)	Sample Size	Grade Level	Internal Consistency Reliability for Different WIHIC Scales	References
Australia Taiwan	1,081	Junior High	0.85 – 0.90	Aldridge et al. (1999); Aldridge & Fraser (2000)
Australia, Canada, United Kingdom	3,980	Grades 8, 10 and 12	0.76 – 0.94	Dorman (2003)
Brunei	1,188	Secondary	0.78 – 0.94	Khine (2002)
Korea	543	Grade 8	0.82 – 0.92	Kim et al. (2000)
India	1,021	Grades 9 and 10	0.58 – 0.83	Koul & Fisher (2005)
Singapore	250	Working Adults	0.74 – 0.92	Khoo & Fraser (2008)
Singapore	1.081	Primary 4, 5 and 6	0.77 – 0.98	Peer & Fraser (in press)
South Africa	1,077	Primary	0.68 – 0.94	Aldridge et al. (2009)
California, USA	745	High School	0.75 – 0.97	Taylor & Fraser (2013)
New York, USA	1,097	Grades 7 and 8	0.94 – 0.95	Cohn & Fraser (2013)
UAE	763	College	0.43 – 0.74	MacLeod & Fraser (2010)

Based on its relevance to my study, the three scales that were selected from the WIHIC are Cooperation, Teacher Support and Involvement. The Cooperation scale measures the extent to which students cooperate instead of competing with one another on learning tasks. The Teacher Support scale measures the extent to which the teacher helps, befriends, trusts and is interested in students. The Involvement scale measures the extent to which students have attentive interest, participate in discussions, do additional work and enjoy the class. While this section provides justification for using WIHIC scales based on statistical quality, justification based on instructional considerations and their ability to provide information about the networked learning community is presented in Section 3.4.4.

The central focus of the Singapore mathematics curriculum is the ability to solve mathematics problems. As outlined in Section 1.2.1, problem solving in Singapore classrooms involves the acquisition and application of mathematics concepts and skills in a wide range of situations, including non-routine, open-ended and real-world problems. Wong (2007) emphasised that a student has to apply four types of mathematical competencies, namely, specific mathematics concepts, skills, processes, and metacognition in order to successfully solve various types of mathematical problems. In my study, the scale of Problem Solving was developed to measure the extent to which students experience the problem-solving process when they solve mathematics problems. An example of an item in this scale is "I can figure out the steps needed to solve a mathematics problem."

The study of learning environments has a theoretical base in the work of Moos (1979). Premised on extensive empirical research, Moos concluded that human environments could be described in terms of three general categories: the Relationship dimension, the Personal Development dimension and the System Maintenance and Change dimension (refer to Section 2.3.1 and Table 2.2). In constructing the instrument, I made sure that all of these three dimensions of Moos' scheme were represented in the MCEA questionnaire. As presented in Table 2.2, Teacher Support and Involvement are Relationship dimensions while Cooperation is a Personal Development dimension. The new Problem Solving scale is a System Maintenance & Change dimension.

3.4.2 Test of Science-Related Attitude (TOSRA)

In my study, student attitude was one of the criteria for assessing the effectiveness of teachers' participation in a mathematics networked learning community. To this end, a review of literature on attitudes was presented in Chapter 2 in Section 2.4.3, including the use of TOSRA and its validation in past research in the original or modified versions (Fraser, 1979; Fraser et al., 2010; Fraser & Butts, 1982; Schibeci & McGaw, 1981; Spinner & Fraser, 2005; Wong & Fraser, 1996).

The TOSRA was developed by Fraser (1978, 1981) to measure seven science-related attitudes among secondary school students based on Klopfer's (1971) categories for the affective domain in science education. The TOSRA consists of 70 items, which are spread equally between seven distinct scales. Each scale contains 10 items, with the responses based on a five-point Likert scale ranging from Strongly Agree to Strongly Disagree. For my study, only one of the constructs (Enjoyment of Science Lessons) was used as it was considered to be centrally relevant to my research questions.

For each scale in the original TOSRA, there are five positively-worded and five negatively-worded statements. Because the scale measuring attitude was placed in the same questionnaire as the learning environment scales, the negatively-worded statements were rephrased as shown in Table 3.2 below. This was to facilitate easy reading and comprehension for the 11-year old students as well as to maintain consistency because there are no negatively-worded statements in the WIHIC. Negative items cause confusion and reduce validity and reliability (Schriesheim, Eisenbach & Hill, 1991; Schriesheim & Hill, 1981).

Table 3.2 Changes Made to the Enjoyment of Science Lessons Scale in TOSRA

Item No	Original Statement in TOSRA	New statement in MCEA
5	Science lessons are fun.	Mathematics lessons are fun.
12	I like science lessons.	I like mathematics lessons.
19	School should have more science lessons each week.	School should have more mathematics lessons each week.
33	Science is one of the most interesting school subjects.	Mathematics is one of the most interesting school subjects.
40	Science lessons are a waste of time.	Mathematics lessons are time well-spent.
47	I really enjoy going to science lessons.	I put effort into mathematics work.
61	I look forward to science lessons.	I look forward to mathematics lessons.
68	I would enjoy school more if there were no science lessons.	I would enjoy school more if there were more mathematics lessons.

Two items (Item 26 and Item 54) in the Enjoyment of Science Lessons scale in TOSRA were removed because they were not centrally relevant to my study. Hence, the Enjoyment scale for my study has only eight items, which is consistent with the other learning environment scales in the MCEA questionnaire. Item 47 of the TOSRA was also rephrased to reflect the nature of learning mathematics which requires students to put in effort to solve the mathematical problems (refer to Table 3.2). The word 'science' also was replaced with the word 'mathematics' in all the statements. In summary, the attitude scale used in this study was derived from the modification of the Enjoyment of Science Lessons scale from the TOSRA and it served as a one-dimensional scale of measuring students' enjoyment of mathematics lessons (Ogbuehi & Fraser, 2007; Spinner & Fraser, 2005).

3.4.3 Mathematics Classroom Environment and Attitude Questionnaire

After the selection of three scales from the WIHIC, development of a new Problem Solving learning environment scale and modification of an attitude scale from the TOSRA, all of these five scales were then assembled into a single questionnaire, called the Mathematics Classroom Environment and Attitude (MCEA) Questionnaire. Having all the scales in a single instrument facilitated administration of the questionnaire and was more user-friendly for students when responding to the 40 items in the questionnaire. On the cover page of the questionnaire, there is a set of instructions and practice example for the students. Descriptive information for MCEA questionnaire (namely, scale descriptions and sample items) is shown in Table 3.3, while the complete MCEA questionnaire is presented in Appendix 1.

In this questionnaire, the WIHIC scales and items were presented first (Items 1 – 24), followed by the newly-constructed Problem Solving scale (Items 25 – 32) and lastly the TOSRA scale (Items 33 – 40). To avoid confusion in responding to the questionnaire, as well as when coding for data analysis, the response alternatives in the original TOSRA were changed from Strongly Agree, Agree, Not Sure, Disagree and Strongly Disagree to Almost Never, Seldom, Sometimes, Often, and Almost Always so that the same five frequency response alternatives could be used for all scales. Item responses were scored 1, 2, 3, 4 and 5, respectively, with 5 representing the most positive response.

Table 3.3 Descriptive Information for Five Scales in MCEA Questionnaire

Scale Name	Scale Description	Sample Item
Cooperation	The extent to which students cooperate rather than compete with one another on learning tasks.	Students work with me to achieve class goals in mathematics.
Teacher Support	The extent to which the teacher helps, befriends, trusts and is interested in students.	The teacher helps me when I have trouble with mathematics problem.
Involvement	The extent to which students have attentive interests, participate in discussions, do additional work and enjoy the class.	I explain my ideas for solving mathematics problems to other students.
Problem Solving	The extent to which students experienced the processes in mathematical problem solving	I know what questions to ask myself to solve a mathematics problem.
Enjoyment	The extent to which students enjoy the mathematics lessons.	Mathematics lessons are time well-spent.

3.4.4 Justification for the Choice of Scales

Typical mathematics classrooms in Singapore are predominantly teacher-centred with little opportunity for students to engage in discussions of mathematical ideas. Therefore, there was a deliberate effort to shift teachers' practice towards a more student-centred pedagogy with a constructivist orientation during the networked learning. Because of these efforts, the scales (Cooperation, Teacher Support, Involvement and Problem Solving) in the MCEA questionnaire were chosen to provide information about these aspects of the learning environment as perceived by the students of these teachers who had participated in networked learning.

When making sense of mathematical ideas, students need opportunities to work both independently and collaboratively. Whilst having independent thinking time is important for students for grasping a new concept, it is equally important that teachers encourage a collaborative learning environment in which students work together to find a solution. Such learning behaviours are considered desirable (Johnson, Johnson & Smith, 2007; Tan, Sharan & Lee, 2007) and learning experiences should provide opportunities for students to collaborate with and learn from each other. It was with this intention that the Cooperation scale was selected for my study to assess the extent to which students work with one another to achieve the learning goals in mathematics.

Geneva Gay (2000 p. 197) writes that “I think interpersonal relations have a tremendous impact on the quality of teaching and learning. Students perform much better in environments where they feel comfortable and valued. Therefore, I work hard at creating a classroom environment and ambiance of warmth, support, caring, dignity, and informality. Yet these psycho-emotional factors do not distract from the fact that my classes are very demanding intellectually. Students are expected to work hard and at high levels of quality.” If students consider a teacher to be approachable and interested in them, then they are more likely to seek the teacher’s help if they encounter a problem with mathematics. The support from a teacher helps to give students the courage and confidence needed to tackle new problems, take risks in their learning, and work on and complete challenging tasks. Because the teacher’s relationship with his or her students is a critical aspect of any learning environment, the second scale, Teacher Support, was included to assess the extent to which the teacher helps, relates to, trusts and is interested in students.

Research has shown that involving students in interacting with the mathematics and with one another promotes understanding (Kazemi & Stipek, 2001; Peressini & Kruth, 2000). According to the Primary Mathematics Teaching and Learning Syllabus (CPDD, 2012, p. 23): “The learning of mathematics should focus on understanding, not just recall of facts or reproduction of procedures….students must be given opportunity to present their ideas using appropriate mathematical language and methods.” To assess the extent to which this is happening in the learning environment, the Involvement scale was selected because it is premised on the notion that classroom talk can support and promote student learning in mathematics both directly and indirectly (Chapin, O’Connor & Anderson, 2009). Instead of only listening passively to the teacher, providing students with the opportunity to participate in classroom discussions and to negotiate ideas and understandings with peers are important aspects of the learning process. This Involvement scale assesses the extent to which students feel that that they have opportunities to participate in discussions and have attentive interest in what is happening in the classroom.

Mathematical problem solving is central to mathematics learning (CPDD, 2012) in Singapore. Problem solving is a process of thinking mathematically. It is not only a goal of learning mathematics but also a major means of doing so (Sherman, Richardson & Yard, 2009). It is important to understand how to find solutions to a problem and to have an awareness of the problem-solving strategies that improve students' willingness to attempt to solve problems, as well as students' abilities to select the appropriate strategy and to implement it effectively to arrive at the correct solution. The newly-constructed scale of Problem Solving therefore assesses students' behaviours during mathematical problem solving.

Attitude is one of the components in the Singapore Mathematics Framework (CPDD, 2012). In the Primary Mathematics Teaching and Learning Syllabus (CPDD, 2012, p. 19), attitudes refer to the affective aspects of mathematics learning such as interest and enjoyment in learning mathematics. Research has shown that students' attitudes towards mathematics influence their achievement and that students who enjoy mathematics tend to perform well in their coursework (McREL Research and Writing Team, 2010). In contrast, students who dislike mathematics tend not to do well in these mathematics classes. A student with a positive attitude finds meaning in learning mathematics and believes that it is worthwhile to put in effort in learning mathematics. Attitudes are therefore considered to be factors that affect academic achievement. In this study, attitudes refer to students' reactions to learning mathematics and classroom instructions, and hence the Enjoyment scale was selected to measure the extent to which students enjoy mathematics lessons.

3.5 DATA SOURCES

The sample chosen for my investigation of the effectiveness of teachers' participation in a networked learning community was strictly based on teachers' willingness to participate. To collect data from students, I invited five teachers from a networked learning community who were, first, interested in participating in this research and, second, able to enlist another teacher from each of their respective schools who was not in the networked learning community and who would be part of a comparison group. The next few sections describe the process of getting access to the sample and the challenges faced in the sampling.

3.5.1 Process and Ethics

To satisfy ethical requirements in research involving humans, I applied for approval of research with low risk through submitting Form C to Curtin University. I also wrote to the Data Administration Centre of the Ministry of Education in Singapore to request approval to collect data from schools. For this, I needed to provide information about the objectives of my research, the number of schools that I intended to approach, the number of students from whom I needed to collect the data in each school and the questionnaire that I would be using in the study.

Once I had the approvals from Curtin University and Data Administration Centre, I sent an email to the principals of the five schools (Appendix 2), which had teachers in the networked learning community who had volunteered to participate in my study, to request for permission to collect data from their students. I had favourable replies from the principals of four schools. However, one of the principals did not allow her teachers and students to participate in this study because the school was already involved in other projects. Therefore, I had to invite another teacher in the mathematics networked learning community to participate in this study and also to seek approval from her principal for data collection.

With the approval from the principals, the teachers in the networked learning community were empowered to approach another teacher in their respective schools, who was not in the networked learning community, to request that their students to respond to my questionnaire to collect the pretest and posttest data. The teacher in the networked learning community was my liaison person in each school for coordinating the administration of the questionnaire (e.g., deciding a common day for the survey within their own school and collecting the questionnaires for the two classes). The survey for all the five schools was administered within Term 3 Week 1 for the pretest and Term 4 Week 3 for the posttest in year 2012. Letters were written to the ten teachers explaining the intent of my study and to seek their help in administering the questionnaire in their mathematics classes. Letters requesting consent were also given to parents to seek their permission for their children to be involved in the research.

3.5.2 Challenges

My original intent was for the sample in the experimental group to be mainly from a mixed-ability class. Thus, I approached a newly-formed networked learning community that focuses on designing learning tasks in mathematics. As I was unable to get five teachers of Primary 5 mathematics from this network to participate in this study, I had to approach teachers from another networked learning community which was in the process of firming up a date to meet in Term 3 Week 2. This community of teachers were interested in collaborating to exchange ideas and strategies for teaching low-progress learners in mathematics.

Because the timing of their first professional learning satisfied my requirements and there were five teachers in the network who were interested in participating in my study, I used the students of these teachers as my sample group. The drawback with this sample was that the teachers were all taking the weakest students in Primary 5 Standard Mathematics in their respective schools. Therefore, it was not possible to find another class of comparable abilities in mathematics in their respective schools. Although I had advised these teachers to approach another teacher who was teaching the next weakest class in mathematics in order to provide a comparison class, only one teacher was able to do so. The other four teachers actually got the teacher who was teaching an average-ability or high-ability class in mathematics to be in the comparison group. This situation was beyond my control because it was strictly based on the teacher's willingness to participate in the study.

3.6 DATA COLLECTION

As mentioned earlier, five Primary 5 mathematics teachers from the same networked learning community responded to an invitation to participate in this research. Each of the five teachers was from a different school and each teacher arranged for another Primary 5 mathematics teacher in his/her respective school to administer the MCEA questionnaire to his/her mathematics class. The mathematics classes of teachers who were not in the networked learning community formed the comparison group, while the mathematics classes of teachers who were in the networked learning community formed the experimental group for the study. Data collection for this study involved two phases. The first phase was a pilot study (Section 3.6.1) aimed at ensuring that the instrument was comprehensible to the target audience. The second phase involved data collection for the main study which is described in details in Section 3.6.2.

3.6.1 Pilot Study

Before gathering data from the 375 Primary 5 students from 10 mathematics classes in five different schools, the MCEA questionnaire was pilot-tested with a sample of 20 Primary 5 students from a class in a school which was not included in the study. Anderson (1998, p. 179) advocated that "pilot-testing will identify ambiguities in the instructions; it will help clarify the wording of the questions, and it may alert you to omissions or unanticipated answers in multiple choice or ranking questions". This pilot-testing was essential to check if the wording of the questions was suitable for Primary 5 students in Singapore. The students were asked to underline the part of any statement that was confusing or unclear to them. The time taken for all the students to complete the questionnaire was also recorded.

The maximum time taken by the students to complete the questionnaire was about 15 minutes. Based on this information, I requested half an hour from the schools for conducting the questionnaire during the main study. This provided sufficient time for the logistics of distributing and collecting questionnaires and giving instructions to the students and for students to complete the questionnaire without rushing.

Although the items in the questionnaire were clear to the students, there were some questions from the students about the meaning of 'almost never' and 'almost always' used in the response scale. They were told that 'almost never' means that it did not take place at all or it happened only once over a period of one ten-week term. 'Almost always' was described as meaning that the practice took place in every lesson or it didn't take place only once or twice over a period of ten-week.

3.6.2 Main Study

The purpose of this phase of study was to collect the data needed to answer the research question about the effectiveness of teachers' participation in mathematics networked learning community. In the main study, there were two instructional groups: the experimental group consisting of those classes for which the teachers participated in networked learning community; and the comparison group for which the teachers did not participate in networked learning community. Regardless of whether the classes were taught by teachers who participated in networked learning or not, similar topics were taught in the mathematics lessons for both the experimental group and the comparison group.

According to the teachers in the networked learning community, the students in the experimental group generally had short attention-spans and they liked to talk. Although they struggled with mathematics language, they liked to participate in discussions. Three classes in the comparison group were considered by their teachers to be attentive in class and serious in their work. Two classes in the comparison group were described as active and talkative. The teachers needed to spend some time in gaining students' attention and getting them to focus on their work. The teachers in the comparison group also mentioned that their students were not very good at using mathematics language to articulate their mathematical thinking. Although there were some differences between the students in the experimental and comparison groups, I don't believe that they would influence my findings because statistical analyses were based on pre–post changes within respective groups.

The questionnaires for the pretest and posttest administrations were sent by mail to the respective schools one week before the scheduled time-frame for students to take the survey. I enclosed an instruction sheet for all of the participating teachers to guide them in administering the questionnaire. The teachers personally administered the questionnaire to their respective classes so that they could answer any questions that the students might have. Students were informed that, even though details about their name, class, gender, name of mathematics teachers, and school were requested on the cover of the questionnaire, their responses would be coded anonymously. This was to maintain confidentiality. The questionnaires for each class were collected in separate envelopes and handed directly to the researcher for data entry. The pretest data were collected during 2012 in Term 3 Week 1, while the posttest data were collected in Term 4 Week 3 of the same year. Students who were on medical leave when the survey was administered responded to the questionnaire on the first day after they returned to school. Those who returned to school after the survey time-frame did not respond to the survey. The MCEA questionnaire was administered to 394 students during the pretest and 389 students during the posttest.

After the pretest and posttest questionnaire had been administered, each student's responses were checked and matched for data entry. For a few students who had left one page or one scale blank on the pretest or posttest MCEA questionnaire, their data were omitted. A research assistant was engaged to enter the rest of the responses (375 students) into a database using the Microsoft Excel software. After entry into the Excel file, the responses keyed in were randomly selected for checking of accuracy in data entry.

The responses of Almost Never, Seldom, Sometimes, Often and Almost Always were entered as 1, 2, 3, 4 and 5, respectively, into the database. Other important information such as questionnaire number, class number and instructional group were also entered directly from the questionnaire into the database. Information such as school was alphabetically coded (e.g., EC for East Coast Primary). The data were then transferred to statistical analyses software, SPSS, to carry out the analyses.

3.7 DATA ANALYSIS

Analysis of the pretest and posttest data from my questionnaire for my sample of 375 students enabled me to make sense of teachers' participation in the networked learning communities and their teaching practices in the classroom as observed by their respective students. Hence, this section describes the statistical analyses conducted to answer my research questions concerning the validity and reliability of the MCEA questionnaire, associations between the learning environment and attitudes, and the effectiveness of teachers' participation in networked learning community. The research questions are listed in Section 3.2.

3.7.1 Research Question 1: Validity and Reliability of MCEA Scales

Factor analysis, Cronbach alpha reliability and one-way ANOVA were used to examine the reliability and validity of the MCEA questionnaire when used with Primary 5 students in Singapore. Factor analysis is a data-reduction technique used to reduce a large number of items to a smaller set of underlying factors (Coakes &

Ong, 2010). It is a method of modelling the covariation among a set of observed variables as a function of one or more latent constructs. The term ‘construct’ refers to an unobservable but theoretically defensible entity, such as attitude. The purpose of factor analysis is to assist researchers in identifying and/or understanding the nature of the latent constructs underlying the variables of interest. In my study, factor analysis was conducted to determine whether the 40 items from the MCEA questionnaire measured four independent dimensions of the learning environment (Cooperation, Teacher Support, Involvement and Problem Solving) and one dimension of Attitude towards mathematics.

The internal structure of the 40 items of the learning environment and attitude scales was examined by separately subjecting the pretest and posttest data to principal axis factoring with varimax rotation and Kaiser normalisation. A varimax rotation (orthogonal factor rotation) produces the maximum distinction between factors. So, using rotation, the factor analysis works to create factors which are as separate, or unique, from each other as possible (Hinton, 2004). A rotation method separates factors that are as different from each other as possible and facilitates interpretation of the factors by putting each variable primarily on one of the factors.

Factor loadings indicate the strength of the relationship between an item and a construct. The stronger an item loads onto a factor or construct, the more that item defines the factor. My criteria for an item to be retained were that it must have a factor loading of at least 0.35 on its *a priori* scale and less than 0.35 on every other scale. The removal of items not meeting these criteria improves the internal consistency and factorial validity of the instrument. The percentage of the total variance extracted with each factor and the eigenvalue for each scale were also calculated.

Reliability indicates the extent to which a group of items “hang together” and measure the same thing (Huck, 2012, p. 71). In my study, I used a questionnaire with the five response options for each statement extending from “almost never” to “almost always” and being scored with the integers 1 to 5. I chose Cronbach’s alpha coefficient to evaluate the internal consistency of each MCEA scale because it is versatile and can be used with instruments made up of items that can be scored with three or more possible values. Cronbach’s alpha provides an indication of the average correlation among all of the items that make up a scale. The magnitude of the alpha coefficient depends on the number of items and on the strength of the correlations among the items. Alpha coefficient values range from 0 to 1, with higher values indicating greater reliability.

The level of confidence which researchers can have in the results obtained from using any instrument is dependent on its validity and reliability. The discriminant validity or independence indicates the extent to which each scale of the MCEA questionnaire measures a unique dimension that is not included in another scale of the instrument. The factor analysis provided support for the independence of factor scores and evidence relevant to the discriminant validity of the WIHIC and attitude scales. As a convenient index of the discriminant validity of raw scores on different scales, the mean correlation of one scale with other scales in the modified WIHIC and each attitude scale, was calculated for the pretest and posttest data gathered from my sample of 375 Primary 5 students.

One-way ANOVA was used to check the ability of each learning environment scale in the MCEA questionnaire to differentiate between the perceptions of students with different teachers. The ANOVA results show whether students with the same teacher perceived the learning environment similarly, while the perceptions of students with different teachers varied. The eta^2 statistic, which is a ratio of 'between' to 'total' sums of squares, was calculated to indicate the degree of association between class membership and the dependent variable for each of the learning environment scales.

3.7.2 Research Question 2: Associations between Learning Environment and Student Attitudes towards Mathematics

The second research question of this study involved associations between students' perceptions of the learning environment and their attitudes towards mathematics. Simple correlation and multiple regression analyses were used to investigate relationships between students' perceptions of their learning environment and the student outcome of attitudes toward mathematics (Enjoyment).

Simple correlation was used to examine the bivariate relationship between the Enjoyment scale and each environment scale of the MCEA questionnaire. Multiple regression analysis was performed to examine the joint influence of the whole set of environment scales on each attitude scale, as well as to identify which environment scales contributed most to variance in students' attitudes when other environment scales were mutually controlled. This information was provided by the standardised regression weight (β) which describes the association between a particular learning environment scale and an outcome when all other learning environment scales were mutually controlled. The objective of this analysis was to identify which of the four scales of the MCEA questionnaire contributed most to the multivariate associations between learning environment and student attitudes.

3.7.3 Research Question 3: Effectiveness of Networked Learning Community

After validating the questionnaire with a sample of 375 students, the effectiveness of teachers' participation in a mathematics networked learning community in this study was investigated through the use of effect sizes and a one-way multivariate analysis of variance (MANOVA). Differences between pretest and posttest scores for students' perceptions of the learning environment and attitudes were analysed separately for the comparison and experimental groups.

In the one-way MANOVA, the dependent variables were the scales from the MCEA questionnaire and the independent variable was the time of testing (i.e. pretest vs. posttest). MANOVA was conducted separately for the experimental group (classes taught by teachers who participated in networked learning) and for the comparison group (classes taught by teachers who did not participate in networked learning). The MANOVA results provided important information about the statistical significance of pretest–posttest differences for each of the groups. The Wilks' lambda criterion is a test statistic used in MANOVA to test the null hypothesis that the group means are all equal. Because the multivariate test using Wilks' lambda criterion yielded significant differences for the pre–post changes in the set of five scales in the MCEA questionnaire, the univariate ANOVA was interpreted separately for each scale.

To determine the magnitude of these pretest–posttest differences and their educational importance, effect sizes (differences between means expressed in standard deviation units) were calculated. According to Huck (2012), the effect size (*d*) refers to an a priori specification of what constitutes the smallest study finding that the researcher considers being worth talking about. The concept of effect size, which indicates the magnitude of a difference, was used to address the notion of practical significance of this study. Cohen (1988) describes an effect size as small, medium and large. Because the effect size does not change as drastically as *p*-values when the sample size is larger, it facilitates the interpretation of the substantive, as opposed to the statistical, significance of a research result. As it is considered to be a good practice to report effect sizes in presenting empirical research finding, the index *d* was computed as the difference between the two sample means divided by the pooled standard deviation to determine the effect size for the pre–post difference for each of the learning environment and attitude scales in my data analysis.

3.8 SUMMARY

This chapter discussed the methods used in this study. Besides reiterating the rationale and objectives of my research, this chapter also provided details of my sample's size, selection and characteristics, described the study's design, instrumentation, data collection and data analysis, and identified challenges faced in collecting the data.

The main goal of this research was to determine the effectiveness of teachers' participation in a mathematics networked learning community in terms of the learning environments created by these teachers in their mathematics classrooms in their respective schools, as well as their students' attitudes towards mathematics. The objectives of this study and the research questions were highlighted in Section 3.2.

As only quantitative data were gathered for the study, a pretest–posttest quasi-experimental design was used to compare the changes in classroom environment and attitudes of those classes whose teachers' participated in networked learning community with those classes whose teachers were not in networked learning community. The research design was discussed in Section 3.3.

Section 3.4 provided background details about the instrument, the MCEA questionnaire, which is mainly based on scales from the WIHIC and TOSRA. It gave an overview of the origin of WIHIC, the pervasive use of the WIHIC in various studies and the three scales (Cooperation, Teacher Support and Involvement) that were selected from the seven scales in the WIHIC. An overview of the internal consistency reliability reported for WIHIC scales in different countries and grade levels was presented in Table 3.1. Also described was the newly-constructed Problem Solving scale to assess students' behaviours during mathematical problem solving. In addition to a brief description of TOSRA, the changes made to the Enjoyment of Science Lessons scale in TOSRA for my study were also presented in Table 3.2. This section also discussed the scales used in the study and how the questionnaire was put together. Descriptive information for the five scales in the MCEA questionnaire was presented in Table 3.3.

Section 3.5 focused on the data sources for this study. The selection of the sample, the challenges faced and the ethical issues involved in inviting teachers to participate in this study are described in this section. Five Primary 5 mathematics teachers from the same networked learning community responded to an invitation to participate in this research. Each of the five teachers was from a different school and each teacher arranged for another Primary 5 mathematics teacher in his/her respective school to administer the MCEA questionnaire to his/her comparable mathematics class. The mathematics classes of teachers who were not in the networked learning community formed the comparison group for the study. The sample consisted of 375 Primary 5 students from 10 mathematics classes in five schools.

As reported in Section 3.6, there were two phases of data collection. In the pilot phase, data were collected to check the readability of the MCEA questionnaire with a group of 20 Primary 5 students. In the main study, the MCEA questionnaire was administered at the beginning and at the end of a 12-week period. For both the pretest and posttest data, the frequency response options of Almost Never, Seldom, Sometimes, Often, and Almost Always were scored 1–5, respectively, for statistical analysis with SPSS.

Finally, Section 3.7 discussed how the data from the sample of 375 students were analysed to answer the three research questions. To answer the first research question, pretest and posttest data from the MCEA questionnaire were analysed separately using principal axis factoring followed by varimax rotation and Kaiser normalization to check the factor structure of the questionnaire. Cronbach alpha reliability, discriminant validity and ability to differentiate between classrooms (one-way ANOVA) were used to provide further evidence of the validity and reliability of the instrument.

For the second research question, simple correlation and multiple regression analyses were used to examine associations between the learning environment and attitudes towards mathematics. While the simple correlation shows the bivariate relationship between each learning environment scale and the attitude scale, multiple regressions analysis provides information on the multivariate relationship between the set of learning environment scales and the attitude scale. Regression coefficients were used to identify which learning environment scales were significantly related to an attitude dimension when all other MCEA scales were mutually controlled.

To answer the third research question, pre–post changes in learning environment and enjoyment scales were used to evaluate the effectiveness of teachers' participation in a networked learning community. MANOVA with repeated measures for pretest–posttest changes in scores for the MCEA scales was conducted separately for experimental students (whose teachers had participated in networked learning community) and comparison students (whose teachers had not participated in networked learning community). The effect size for pre–post differences for each scale was calculated separately for experimental and comparison groups to provide insights into the magnitude and practical significance of differences and to clarify further the patterns of similarities and differences between experimental and comparison students.

Chapter 4

ANALYSES AND RESULTS

4.1 INTRODUCTION

This chapter describes data analyses and reports findings based on the quantitative data collected using a modified version of the What Is Happening In this Class? (WIHIC) questionnaire and items from the Test of Science-Related Attitudes (TOSRA). To examine the factorial validity and internal consistency reliability of these scales, factor structure, Cronbach alpha reliability, discriminant validity, and ability to differentiate between the perceptions of students in different classes were examined. Simple correlation and multiple regression analyses were used to explore relationships between student perceptions of the learning environment and student attitudes. The effectiveness of teachers' participation or non-participation in mathematics networked learning community was explored using one-way MANOVA and effect sizes to investigate pretest−posttest changes in environment and attitudes and to compare these for two groups of teachers (experimental and control).

A survey called the Mathematics Classroom Environment and Attitude (MCEA) questionnaire was administered to 394 students during the pretest and 389 students during the posttest (as described in Section 3.6.2). The MCEA questionnaire comprises three scales from the WIHIC (Cooperation, Teacher Support and Involvement), the newly-constructed learning environment scale of Problem Solving and the scale of Enjoyment which was modified from the TOSRA. The survey was administered to the classes of 5 teachers involved in the networked learning community and to the classes of 5 teachers who were not involved in the networked learning community. All of the students were from Primary 5 Mathematics classes from five different schools in Singapore. There was attrition in the number of responses between the pretest and posttest data because of student absences either during the pretest or posttest administration. There were also incomplete responses to the survey. The final total number of students with complete responses considered for this study was 375.

As reported in Chapter 3, a pretest–posttest quasi-experimental design was used to compare the changes in classroom environment and attitudes of those classes whose teachers participated in networked learning community with those students whose teachers were not in the networked learning community. The MCEA questionnaire was administered at the beginning and the end of a 12-week intervention. Students' responses to the five frequency alternatives of Almost Never, Seldom, Sometimes, Often and Almost Always for the MCEA questionnaires were assigned 1, 2, 3, 4 and 5, respectively, for statistical analysis with SPSS. All of the survey responses from the pretest and posttest were used to validate the MCEA questionnaire, to determine associations between student attitudes and the learning environment, and to evaluate the effectiveness of teachers' participation in a mathematics networked learning community in terms of students' classroom environments and attitudes to mathematics in Singapore. This chapter is devoted to describing the data analyses and findings for the following three research questions in my study:

1. To ascertain the validity and reliability of the MCEA questionnaire for assessing students' perceptions of the learning environment and attitudes to mathematics in Primary 5 mathematics classrooms in Singapore.
2. To investigate associations between students' perceptions of their classroom environment and their attitude to mathematics
3. To evaluate the effectiveness of teachers' participation in a mathematics networked learning community in terms of their students':
    a. Perceptions of classroom learning environment
    b. Attitudes to mathematics.

4.2 RESEARCH QUESTION 1: VALIDITY OF QUESTIONNAIRE

The responses from the sample of 375 students in 10 classes were used to ascertain the factorial validity and internal consistency reliability of the MCEA questionnaire in assessing students' perceptions of the learning environment and attitudes to mathematics in the Singapore Primary 5 mathematics classrooms. This section reports the factor structure of the MCEA questionnaire (Section 4.2.1), its internal consistency reliability (Section 4.2.2), discriminant validity (Section 4.2.3), and its ability to differentiate between classes (Section 4.2.4), as well as the consistency of my findings with past research using the WIHIC (Section 4.2.5).

4.2.1 Factor Structure of the MCEA Questionnaire

Pretest and posttest data from the MCEA questionnaire were analysed separately using principal axis factoring followed by varimax rotation and Kaiser normalization to determine the factorial validity of the questionnaire. The criteria for the retention of any item were that its factor loading of at least 0.35 on its own scale and less than 0.35 on all other scales. The application of these criteria led to the removal of three items from the Problem Solving scale. These three items (namely, Item 30: I receive feedback from my classmate on the way I solve a mathematics problem; Item 31: I use feedback to improve the way I solve a mathematics problem; and Item 32: I know the steps that my classmate takes to do a mathematics problem) were removed to improve the internal consistency reliability and factorial validity of the MCEA questionnaire. However, the remaining five items, which provide information about problem-solving behaviour such as ‘knowing the steps that a teacher takes to solve a problem’, ‘what questions to ask myself to solve a mathematics problem’, and how ‘to self-correct when I made a mistake’ were able to capture the construct of problem solving fully. Therefore, the removal of three items would not appreciably affect the interpretations of any findings.

The factor loadings for each MCEA item for the sample of 375 students in the 10 classes are shown in Table 4.1. Item numbers shown in the table are listed in the order in which they appear in the survey that was administered to students (Appendix A). The three items from the Problem Solving scale with factor loadings of less than 0.35 have been omitted in this table. With the removal of three items, factor analysis for the remaining 37 items revealed that all five a priori scales of the MCEA were retained. For the remaining 37 items shown in Table 4.1, every item had a loading of at least 0.35 on its own scale and less than 0.35 on each of the other four scales for both the pretest and posttest data. The percentage of the total variance extracted with each factor and the eigenvalue for each scale are also recorded at the bottom of Table 4.1.

TABLE 4.1 Factor Analysis Results for Learning Environment and Attitude Scales for Pretest and Posttest

Item	Factor Loadings									
	Cooperation		Teacher Support		Involvement		Problem Solving		Enjoyment	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Coop1	0.60	0.62								
Coop 2	0.56	0.57								
Coop 3	0.54	0.59								
Coop 4	0.52	0.49								
Coop 5	0.54	0.40								
Coop 6	0.66	0.35								
Coop 7	0.69	0.66								
Coop 8	0.54	0.54								
TeaSup 1			0.65	0.69						
TeaSup 2			0.68	0.70						
TeaSup 3			0.69	0.71						
TeaSup 4			0.58	0.60						
TeaSup 5			0.64	0.64						
TeaSup 6			0.72	0.69						
TeaSup 7			0.65	0.58						
TeaSup 8			0.44	0.52						
Invo 1					0.50	0.52				
Invo 2					0.73	0.58				
Invo 3					0.48	0.35				
Invo 4					0.64	0.59				
Invo 5					0.57	0.48				
Invo 6					0.57	0.61				
Invo 7					0.35	0.49				
Invo 8					0.55	0.51				
ProbSol 1							0.63	0.64		
ProbSol 2							0.66	0.70		
ProbSol 3							0.65	0.63		
ProbSol 4							0.55	0.58		
ProbSol 5							0.51	0.38		
Enjoy 1									0.75	0.75
Enjoy 2									0.84	0.81
Enjoy 3									0.81	0.82
Enjoy 4									0.83	0.84
Enjoy 5									0.82	0.81
Enjoy 6									0.71	0.65
Enjoy 7									0.47	0.46
Enjoy 8									0.81	0.76
% Variance	6.31	4.23	9.49	7.55	5.06	6.29	3.91	3.37	32.75	36.13
Eigenvalue	2.46	1.69	3.73	3.02	1.97	2.52	1.52	1.35	12.77	14.45

N= 375 students
Factor loadings less than 0.35 have been omitted from the table.
Principal axis factoring with varimax rotation and Kaiser normalization.

The percentage of variance accounted for by the different MCEA scales ranged from 5.06% to 32.75% for the pretest data, whereas the range for the posttest data was from 3.37% to 36.13%. The total variance was 57.52% for pretest data and 57.57% for posttest data. The Enjoyment scale accounted for most of the total variance

(32.75% for pretest data and 36.13% for posttest data). Eigenvalues associated with different factors ranged from 1.52 to 12.77 for pretest data and from 1.35 to 14.45 for the posttest data. The results of the factor analysis, shown in Table 4.1, strongly support the factorial validity of the MCEA questionnaire for my sample of Primary 5 Mathematics students in Singapore.

4.2.2 Internal Consistency Reliability of MCEA Questionnaire

The Cronbach alpha coefficient was used as the index of scale internal consistency of MCEA scales. Table 4.2 shows that the alpha reliability coefficient for the different MCEA scales ranged from 0.85 (Cooperation) to 0.94 (Enjoyment) for the pretest and from 0.78 (Cooperation) to 0.94 (Enjoyment) for the posttest. The attitude scale (Enjoyment) based on the TOSRA had the highest alpha reliability at 0.94, suggesting that the attitude scale was highly reliable when used with this sample of elementary school students in Singapore. These values suggest satisfactory internal consistency reliability for all the MCEA scales and are very similar to those reported by Aldridge et al. (1999) for the WIHIC, which ranged from 0.85 to 0.90 with a sample of 1879 Grade 7–9 students from 50 classes in Taiwan.

TABLE 4.2 Scale Mean, Standard Deviation, Internal Consistency (Alpha Reliability), Discriminant Validity (Mean Correlation), Ability to Differentiate between Classes (ANOVA Results) for the MCEA Questionnaire

Scale	Form	Mean	SD	Alpha Reliability	Mean Correlation	ANOVA Eta^2
Cooperation	Pre	3.34	0.79	0.85	0.48**	0.13**
	Post	3.55	0.84	0.78	0.50**	0.12**
Teacher Support	Pre	3.45	0.88	0.89	0.50**	0.18**
	Post	3.45	0.88	0.89	0.51**	0.21**
Involvement	Pre	3.02	0.83	0.86	0.53**	0.15**
	Post	3.14	0.92	0.86	0.55**	0.14**
Problem Solving	Pre	3.30	0.77	0.80	0.51**	0.14**
	Post	3.58	0.82	0.84	0.51**	0.20**
Enjoyment	Pre	3.50	1.05	0.94	0.42**	
	Post	3.65	1.09	0.94	0.51**	

**$p<0.01$

N=Total 375 students

Item means and standard deviations were also computed to portray the nature of the mathematics learning environment and students' enjoyment in learning mathematics. The mean scores (see Table 4.2) for the pretest ranged from 3.02 to 3.50 and the range for the posttest was from 3.14 to 3.65. Generally, there was an improvement in the mean scores from pretest to posttest. The standard deviation for all the scales for both the pretest and posttest data was less than 1.09, suggesting that there was limited diversity in students' perceptions of their learning environment and attitudes to mathematics.

4.2.3 Discriminant Validity of MCEA Questionnaire

To check that each scale of the MCEA questionnaire measures a unique dimension, discriminant validity was examined. Discriminant validity is the degree to which the items in a particular scale have a strong relationship with other items in the same scale and a weak relationship with items belonging to other scales in the same questionnaire. This indicates the ability of a scale to predict an independent variable from a set of dependent variables (outcomes). The mean correlation of each scale with the other scales was used as a convenient index of discriminant validity.

The discriminant validity results, which are presented in Table 4.2, indicate that most scales were fairly unique in the dimension that each assessed. Table 4.2 shows that the mean correlation of a scale with the other scales varied from 0.42 to 0.53 for the pretest and from 0.50 to 0.55 for the posttest. These results suggest that raw scores on each scale of the MCEA questionnaire measures a relatively unique but somewhat overlapping dimension. However, the factor analysis results attest to the independence of factor scores.

4.2.4 Ability of the MCEA Questionnaire to Differentiate between Classes

A one-way analysis of variance (ANOVA) was computed to determine the degree to which each learning environment scale of the MCEA questionnaire was able to differentiate between perceptions of students in the different classes. ANOVA indicates if students in the same class perceive their learning environment in a similar way, while the mean class perceptions vary from class to class. The independent variable was class membership (N=10 classes). ANOVA was run for each scale of the MCEA and separately for pretest and posttest data to assess its ability to differentiate between the perceptions of students in the different classes. This characteristic is not relevant for the attitude scale.

The ANOVA results in terms of the eta^2 statistic, which is the ratio of 'between' to 'total' sums of square and represents the proportion of variance accounted for by class membership, are presented in the last column of Table 4.2. The eta^2 statistic ranged from 0.13 to 0.18 for the pretest and 0.12 to 0.21 for the posttest data for the different learning environment scales of MCEA and was statistically significant ($p<0.01$) for each scale on each testing occasion. These results confirm the ability of each scale of the MCEA questionnaire to differentiate significantly between students in the different classes. My results replicate past research which indicated that the scales from the WIHIC are able to differentiate students' perceptions in different classrooms in Australia and Taiwan (Aldridge, Fraser & Huang, 1999), South Africa (Aldridge, Fraser & Sebela, 2004), Australia (Dorman, 2008) and the United States (Ogbuehi & Fraser, 2007; Wolf & Fraser, 2008).

4.2.5 Consistency of Validity Findings with Past Research

Because the MCEA contains three scales (Cooperation, Teacher Support and Involvement) from the WIHIC, a newly-constructed scale called Problem Solving and an Enjoyment scale which was composed of items extracted from the TOSRA, it is worthwhile to compare the internal consistency reliability and factorial validity of MCEA with previous studies involving the WIHIC. The findings from my study are consistent with other research, such as those studies shown in Table 2.3 of Chapter 2, that provide evidence to support the WIHIC's factor structure, reliability, and ability to differentiate between classes.

A study in Singapore by Khoo and Fraser (2008) involving 250 working adults attending courses in five computer education centres supported the validity of a modified version of the WIHIC. In this five-factor questionnaire, the alpha reliability coefficient for different scales of the modified WIHIC ranged from 0.74 to 0.92, which is very similar to results for the MCEA questionnaire.

In a study on 1081 students in 55 classes in Singapore, Peer and Fraser (in press) found satisfactory factor structure, reliability and ability to differentiate between classes for a questionnaire which contained items extracted from the WIHIC, CLES and TOSRA. The percentage of variance for different scales ranged from 1.95% to 27.92%. The total variance reported was 58.9% and the eigenvalues ranged from 1.36 to 19.54.

In Brunei, Khine (2002) conducted a large-scale study to validate a modified 56-item version of the WIHIC among 1,188 students from 54 science classes in 10 secondary schools. The modified WIHIC showed satisfactory factorial validity and internal consistency, with Cronbach alpha coefficients ranging from 0.78 to 0.94. One-way ANOVA results demonstrated that each scale of the modified WIHIC was able to differentiate significantly ($p<0.01$) between students' perceptions in the different classes.

In a cross-validation study, Dorman (2003) provided support for the validity of a modified 42-item version of the WIHIC using a sample of 3,980 Grade 8, 10 and 12 students in Australia, Canada and the United Kingdom. Principal components factor analysis showed that all 42 items of the modified version of the WIHIC had a factor loading of at least 0.40 on their a priori scale and no other scale. In addition, confirmatory factor analysis provided further support for the WIHIC's a priori factor structure across all three countries. Internal consistency reliability analysis revealed Cronbach alpha coefficients ranging from 0.76 to 0.94 for different WIHIC scales in these three countries. Thus, the modified version of the WIHIC has been found to be reliable amongst students in Australia, Canada, and the United Kingdom. Results of discriminant validity analyses (mean correlation of a scale with other scales) and one-way ANOVA (ability of the WIHIC to differentiate between students' perceptions in different classes) supported the validity of the modified version of the WIHIC in all three countries. According to Dorman (2003), the WIHIC is a valid measure of classroom environment that has a wide range of applications, especially in Western countries.

In India, Koul and Fisher (2005) cross-validated and used a translated version of the WIHIC to investigate associations between students' cultural background and their perceptions of their teacher's interpersonal behaviour and classroom learning environment. Based on a sample of 1,021 students from 31 classes in seven co-educational private schools, reliability coefficients for WIHIC scales were found to range from 0.58 to 0.83. The eta^2 values ranged from 0.09 to 0.14 and were found to be statistically significant for each scale, suggesting that the WIHIC is capable of differentiating significantly between classes. Statistical analyses also showed that a Kashmiri group of students perceived their classrooms and teacher interactions more positively than did students from the other cultural groups identified in the study.

In South Africa, Aldridge, Fraser and Ntuli (2009) cross-validated an IsiZulu version of the WIHIC with 1,077 primary-school students. Principal components factor analysis followed by varimax rotation confirmed a refined structure for the instrument comprising 19 items in four scales. For the actual form, Cronbach alpha reliability estimates for different scales ranged from 0.68 to 0.72 using the individual as the unit of analysis and from 0.85 and 0.94 using the class mean as the unit of analysis. For the preferred form, Cronbach alpha reliability estimates for different scales ranged from 0.52 to 0.57 using the individual as the unit of analysis and from 0.86 and 0.88 using the class mean as the unit of analysis.

A cross-national study of classroom environments in Australia and Indonesia was carried out by Fraser, Aldridge and Adolphe (2010) using a modified version of the WIHIC with a sample of 1,161 students (594 students from 18 classes in Indonesia and 567 students from 18 classes in Australia). The study provided strong support for the factorial validity of both the English-language version of the WIHIC when used in Australia and the Indonesian-language version of the WIHIC when used in Indonesia. The Cronbach alpha reliability coefficients for the six scales, using the individual student as the unit of analysis, were high and ranged from 0.82 to 0.92 for Indonesian students and from 0.78 to 0.89 for Australian students.

In validating the HDYFATC questionnaire, which is a modified questionnaire based on WIHIC, Cohn and Fraser (2013) reported a factor analysis for which the percentage of variance varied from 2.70% to 53.38% for different scales, with the total variance accounted for being 76.13%. Similar to my findings, they also found that Enjoyment (53.38%) made the largest contribution to variance.

In a study in South Florida (Allen & Fraser, 2007), scales of the WIHIC were factorially valid and reliable when used with a group of Grade 4 and 5 students, with alpha reliabilities ranging from 0.67 to 0.86. Other past studies in which the WIHIC displayed satisfactory factorial validity and internal consistency reliability include samples from Singapore (Chionh & Fraser, 2009), Australia (Dorman, 2008), the United States (den Brok et al., 2006; Ogbuehi & Fraser, 2007; Wolf & Fraser, 2008), Australia, Canada and United Kingdom (Dorman, 2003) and Australia and Canada (Zandvliet & Fraser, 2004, 2005). In the same vein, the WIHIC scales used in my study (namely, Cooperation, Teacher Support and Involvement) were also found to have satisfactory factorial validity and internal consistency reliability in past learning environment studies.

Satisfactory internal consistency reliability has also been found in a variety of studies involving original, modified and/or translated versions of the TOSRA. Some of this research was conducted in Australia (McRobbie & Fraser, 1993), Brunei (Scott & Fisher, 2004), Singapore (Wong & Fraser, 1996; Wong et al., 1997), Taiwan and Australia (Aldridge, Fraser & Huang, 1999), Indonesia and Australia (Fraser, Aldridge & Adolphe, 2010) and the USA (Martin-Dunlop & Fraser, 2008). The reliability results for the Enjoyment scale in my study are consistent with those of past research involving the TOSRA.

Because the TOSRA demonstrated satisfactory factorial validity, internal consistency reliability and discriminant validity for the pretest and posttest data in my study, it replicates past research (refer to Section 2.3.5.2 for a literature review) which has supported the validity and reliability of the TOSRA. For example, in Australia and Indonesia, Fraser, Aldridge and Adolphe (2010) used the original version of the TOSRA to assess students' attitudes to science with a sample of 1,161 students (594 students from 18 classes in Indonesia and 567 students from 18 classes in Australia).

In the USA, Wolf and Fraser (2008) used one scale of the TOSRA, Enjoyment of Science Lessons, to assess students' attitudes among 1,434 students in 71 classes in New York. In Singapore, Wong and Fraser (1996) used a modified version of TOSRA, called the Questionnaire of Chemistry-Related Attitudes (QOCRA), to assess students' attitudes towards chemistry lessons with a sample of 1,592 final-year (tenth grade) secondary school chemistry students in 56 intact classes in 28 randomly-selected coeducational government schools. This was followed by Quek, Wong and Fraser (2005) who successfully used the QOCRA with a sample of 497 tenth grade students from three independent schools in Singapore.

4.3 RESEARCH QUESTION 2: ENJOYMENT–ENVIRONMENT ASSOCIATIONS

To answer my second research question concerning associations between the learning environment and the student outcome of attitudes toward mathematics (Enjoyment), simple correlation (*r*) and multiple regression analyses were run using the full sample of Primary 5 students (*N* =375). Simple correlations were used to examine the bivariate association between the student outcome of attitudes towards mathematics and each of the four learning environment scales. The multiple correlation (*R*), which describes the multivariate relationships between the attitudinal outcome and the set of learning environment scales, was used to indicate the joint influence of the set of learning environment scales on the outcome of attitude. The regression coefficients were used to identify which environment scales contributed to variance in students' attitudes when all other environment scales were mutually controlled.

Pedhazur (1982) describes various methods in multiple regression analysis (such as stepwise selection or backward elimination) which can be used to enter independent variables progressively into a regression equation in order to reduce the number of independent variables to those that are significantly and independently related to a dependent variable. In my study, because I wanted to be able to compare my results with those in past research, I retained all of my learning environment scales in the regression analysis whether or not they made statistically significant independent contributions. Therefore, my chosen approach in conducting multiple regression analyses involved including every independent variable in every regression analysis.

The paragraphs below report the results of associations between students' perceptions of their learning environment and students' attitudes towards mathematics, as well as providing information regarding the consistency of my findings with past studies.

The results of the simple correlation analysis shown in Table 4.3 suggest a positive and statistically significant (p<0.01) correlation between student attitudes and each of the four learning environment scales (Cooperation, Teacher Support, Involvement, and Problem Solving) for both the pretest and posttest data. For the pretest, correlations ranged from 0.36 for Cooperation to 0.48 for Problem Solving. For the posttest, correlations ranged from 0.44 for Cooperation to 0.57 for Problem Solving.

The multiple correlation (R = 0.55 for pretest and R = 0.66 for posttest) between the four learning environment scales and Enjoyment, as reflected in Table 4.3, was statistically significant for both pretest and posttest data. These multiple correlations

TABLE 4.3 Simple Correlation and Multiple Regression Analyses for Associations between Learning Environment and Enjoyment Scales for Pretest and Posttest Data

Scale	Administration	Associations with Enjoyment	
		r	β
Cooperation	Pre	0.36**	0.03
	Post	0.44**	0.06
Teacher Support	Pre	0.45**	0.27**
	Post	0.54**	0.29**
Involvement	Pre	0.40**	0.03
	Post	0.50**	0.09
Problem Solving	Pre	0.48**	0.33**
	Post	0.57**	0.36**
Multiple Correlation, *R*	Pre		0.55**
	Post		0.66**

p<0.01
N=375

were all statistically significant, indicating that there were associations between the whole set of learning environment scales (Cooperation, Teacher Support, Involvement and Problem Solving) and the attitude scale (Enjoyment). Inspection of the regression coefficients revealed that Teacher Support and Problem Solving were significant independent predictors of Enjoyment for both pretest and posttest data when the other learning environment scales were mutually controlled. Because all statistically significant relationships in Table 4.3 were positive, this suggests a positive link between students' attitudes to mathematics and the four learning environment scales assessed by the MCEA questionnaire.

Because teachers were collaboratively engaged in conversations about the use of questions to probe students' understanding and cooperative learning strategies to structure group activities in the networked learning communities (Section 1.2.2.1), they were more likely to ask questions to elicit students' ideas for classroom discussions (Involvement Scale). When teachers were more intentional in structuring group processes for pair work or small-group discussions, students were more productively engaged in learning from one another and, there was stronger teamwork.

Through discussions in networked learning community, teachers were also more prepared to provide scaffolds during small-group work and whole-class discussions and therefore students experiencing greater teacher support. When students were engaged in explaining their thought processes and building on their classmates' thinking, they were more likely to put effort into mathematics work and find learning mathematics enjoyable. All of these changes in teaching behaviours could lead to the positive change in learning environment experienced by the students in the experimental group. The changes perceived by students in terms of Cooperation, Teacher Support, Involvement and Problem Solving could lead to students having a more enjoyable experience in learning mathematics (for the positive links found between students' attitudes to mathematics and the four learning environment scales).

4.4 RESEARCH QUESTION 3: EVALUATION OF NETWORKED LEARNING COMMUNITY

To answer my third research question about the effectiveness of teachers' participation in a mathematics networked learning community in terms of students' classroom environments and attitudes to mathematics, a one-way multivariate analysis of variance (MANOVA) with repeated measures was conducted separately for the experimental and comparison groups. The four learning environment scales and the student outcome scale (Enjoyment) were the dependent variables and the testing occasion (pretest and posttest) was the independent variable. Because the multivariate tests using Wilks' lambda criterion revealed statistically significant pre–post changes in the set of five learning environment and enjoyment scales as a whole, the individual univariate ANOVA was interpreted separately for each dependent variable. Table 4.4 shows the *F* value and statistical significance from ANOVA, as well as the effect size, for each of the four learning environment scales and Enjoyment. Discussion of the results for the effectiveness of teachers' participation in a mathematics networked learning community is provided in the paragraphs below.

Whereas the ANOVA results provided information about the statistical significance of pre–post changes, effect sizes were also calculated to provide information about the magnitude or educational importance of those changes as advocated by Cohen (1988). The effect size for each scale, which was calculated by dividing the difference between the pretest and posttest means by the pooled standard deviation, expresses the difference in standard deviation units. As discussed in Section 3.7.3, the criteria used to interpret the practical significance of differences in this study were that 0.2, 0.5 and 0.8 standard deviations would represent small, medium and large effect sizes, respectively (Cohen, 1988).

Table 4.4 reports the average item mean and average item standard deviation for each learning environment and enjoyment scale separately for experimental and comparison students and separately for pretest and posttest. The average item mean (or the scale mean divided by the number of items in that scale) permits meaningful comparison of the means of different scales containing differing numbers of items. It also reports, separately for experimental and comparison groups, the statistical significance of pre–post changes for each scale based on ANOVA, as well as the magnitude of the pre–post difference for each scale expressed as an effect size in

TABLE 4.4 MANOVA with Repeated Measures and Effect Sizes for Pre–Post Changes Separately for Comparison and Experimental Groups for each Learning Environment and Enjoyment Scale

Scale	Group	Mean		SD		Difference	
		Pre	Post	Pre	Post	*F*	Effect Size
Cooperation	Comparison	3.46	3.41	0.78	0.83	1.01	-0.06
	Experimental	3.22	3.69	0.77	0.84	2.71**	0.58
Teacher Support	Comparison	3.54	3.20	0.95	0.89	2.42**	-0.37
	Experimental	3.35	3.71	0.80	0.79	2.62**	0.45
Involvement	Comparison	3.22	2.84	0.84	0.83	2.85**	-0.45
	Experimental	2.82	3.43	0.76	0.91	3.21**	0.73
Problem Solving	Comparison	3.34	3.26	0.81	0.80	1.19	-0.09
	Experimental	3.26	3.90	0.73	0.69	3.79**	0.90
Enjoyment	Comparison	3.61	3.37	1.08	1.15	1.40*	-0.21
	Experimental	3.39	3.90	1.00	0.95	2.25**	0.52

N: Total=375 students, Experimental=188, Control=187
*$p<0.05$, **$p<0.001$

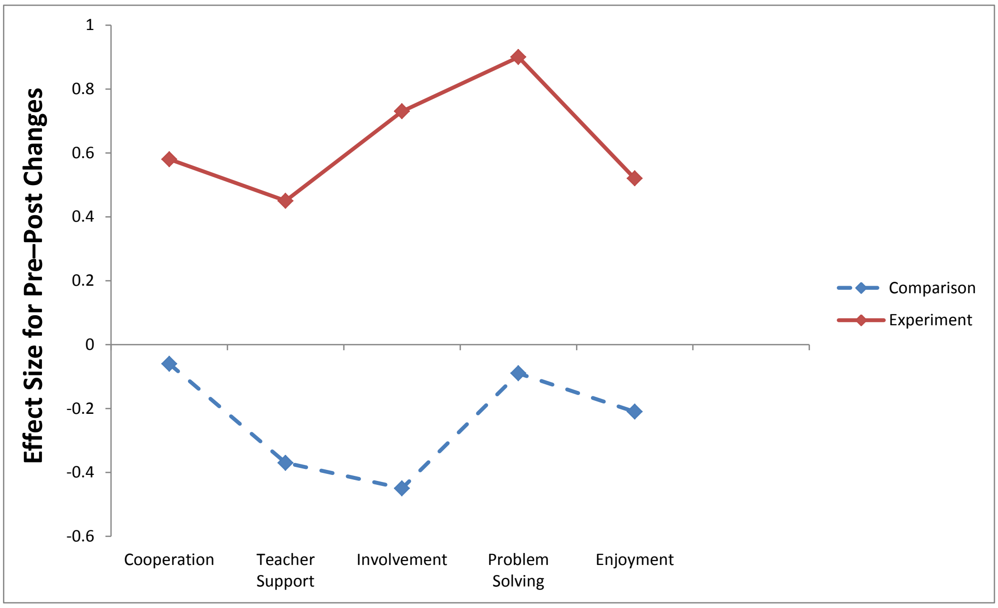


Figure 4.1. Effect Sizes for Pretest–Posttest Changes in Learning Environment and Enjoyment for Comparison and Experimental Groups

standard deviation units. Finally, to clarify further the patterns of similarities and differences between experimental and comparison students, the effect size for pre–post differences for each scale is graphed separately for experimental and comparison groups in Figure 1.

For the comparison group, Table 4.4 and Figure 1 show that pre–post changes in learning environment and enjoyment scales:

- were statistically nonsignificant for two scales (namely, Cooperation and Problem Solving), but statistically significant for the other three scales (Teacher Support, Involvement and Enjoyment).
- represented a decrease between pretest and posttest for every scale.
- were small in magnitude for four scales (0.06 standard deviations for Cooperation, 0.09 standard deviations for Problem Solving, 0.37 standard deviation for Teacher Support and 0.21 standard deviations for Enjoyment) and moderate for Involvement (0.45 standard deviations).

On the other hand, for the experimental group, Table 4.4 and Figure 1 show that pre–post changes in learning environment and enjoyment scales:

- were statistically significant for every learning environment and enjoyment scale.
- represent an increase in scores between pretest and posttest for every scale.
- were moderate to large in magnitude for all scales (ranging from 0.45 for Teacher Support to 0.90 standard deviations for Problem Solving).

Overall the graph in Figure 1 illustrates that pre–post changes were larger in magnitude for the experimental group than for the comparison group for every MCEA scale. Also, scores for every scale increased between pretest and posttest for the experimental group, but decreased for the comparison group. Therefore the results in Table 4.4 and Figure 1 generally provide support for the effectiveness of the networked learning community in terms of classroom learning environment and students' enjoyment of mathematics.

4.5 SUMMARY

This chapter described the analyses and results for my research questions, including validation of the instruments used, associations between classroom learning environment and student attitudes towards mathematics, and an evaluation of the effectiveness of teachers' participation in a mathematics networked learning community in terms of their students' perceptions of classroom learning environment and attitudes to mathematics. The instrument used was the MCEA questionnaire which included modified scales from the WIHIC and TOSRA together with a newly-constructed learning environment scale. A sample of 375 students from five primary schools in Singapore responded to the MCEA questionnaire for the pretest and posttest.

Section 4.2 presented the statistical analyses and interpretations for the validity and reliability of the MCEA questionnaire for assessing students' perceptions of the learning environment and attitudes to mathematics in Primary 5 mathematics classrooms in Singapore. Principal axis factor analysis with varimax rotation and Kaiser normalization was performed separately with the pretest and posttest data for the 40-item, five-scale version of the MCEA questionnaire. Factor analysis allowed checking of whether removing any items would improve the factorial validity of the instrument. An item was retained if it had a factor loading of 0.35 or above with its a priori scale and below 0.35 with each of the other scales. This led to the removal of 3 items, with 37 items being retained in the same 5-factor structure.

The percentage of variance for different scales ranged from 5.06% to 32.75% for the pretest data, and from 3.37% to 36.13% for the posttest data. The total variance was 57.52% for pretest data and 57.57% for posttest data. The Enjoyment scale accounted for most of the total variance (32.75% for pretest data and 36.13% for posttest data). Eigenvalues for the five different scales ranged from 1.52 to 12.77 for pretest data and from 1.35 to 14.45 for the posttest data. This strongly supported the factor structure of the refined 37-item questionnaire and attested to the independence of factor scores on the five scales consisting of three learning environment scales based on the WIHIC, a newly-constructed learning environment scale and an attitude scale based on the TOSRA.

Following that, the internal consistency reliability was estimated using Cronbach's alpha coefficient to check the extent to which the items in each scale assess a similar construct. Using individual student scores as the unit of analysis, the alpha coefficient for the five different scales ranged from 0.85 to 0.94 for the pretest and from 0.78 to 0.94 for the posttest. The highest alpha reliability was obtained for the Enjoyment scale and the lowest for the scale Problem Solving. These internal consistency indices are comparable to those in past studies that have used the WIHIC (Aldridge & Fraser, 2000; Chionh & Fraser, 2009).

The ability of each learning environment scale of the MCEA questionnaire to differentiate between perceptions of students in different classes was determined through a one-way ANOVA. The ANOVA analyses revealed a significant difference ($p<0.01$) between students' perceptions in different classes for each learning environment scales, with eta^2 values ranging from 0.13 to 0.18 for the pretest and from 0.12 to 0.21 for the posttest data for the different learning environment scales of MCEA. These results suggest that the learning environment scales based on the WIHIC were capable of differentiating significantly between different classes in Singapore. The results from this study were also compared with the findings from past research.

Section 4.3 reported the statistical analyses conducted to determine associations between students' perceptions of the learning environment and their attitudes towards mathematics. Simple correlation and multiple regression analyses were used to establish associations between perceptions of the learning environment scales and the attitude scale. The results of the simple correlation analysis indicated that all the four learning environment scales (Cooperation, Teacher Support, Involvement and Problem Solving) were statistically significantly associated with attitudes towards mathematics (Enjoyment). Correlations ranged from 0.36 to 0.48 for the pretest and from 0.44 to 0.57 for the posttest.

The multiple correlation between the four learning environment scales and Enjoyment was statistically significant for both the pretest (R=0.55) and posttest (R= 0.66) data. This supports the conclusion that the nature of the learning environment was related to students' attitudes toward mathematics lessons.

Finally, the effectiveness of teachers' participation in a mathematics networked learning community in terms of learning environment and attitudes to mathematics was reported in Section 4.4 of this chapter. The data from a sample of 375 students from ten classes in five different schools were analyzed through MANOVA with repeated measures to identify whether pretest–posttest changes for those classes whose teachers participated in the networked learning community were different from changes for those classes whose teachers did not.

The results presented in Table 4.4 and Figure 1 show that the pre–post changes were larger in magnitude for the experimental group than for the comparison group for every MCEA scale. For the comparison group, pre–post changes in learning environment and enjoyment scales were statistically nonsignificant for two scales (namely, Cooperation and Problem Solving), but statistically significant for the other three scales (Teacher Support, Involvement and Enjoyment). Although every scale showed an improvement between pretest and posttest data, pre–post differences for these scales were small in magnitude, ranging from 0.06 standard deviations (Cooperation) to 0.45 standard deviations (Involvement).

In contrast, the pre–post changes in learning environment and enjoyment scales for the experimental group were statistically significant for every learning environment and enjoyment scale. There was an increase in scores between pretest and posttest which ranged from moderate to large in magnitude for all scales, ranging from 0.45 for Teacher Support to 0.90 standard deviations for Problem Solving. Generally, these statistical analyses with MANOVA provided support for the effectiveness of the networked learning community in terms of classroom learning environment and students' enjoyment of mathematics.

The constraints, significance and limitations of my study, as well as recommendations for future research, are outlined in Chapter 5.

Chapter 5

SUMMARY AND DISCUSSION

5.1 INTRODUCTION

I employed a learning environment framework to evaluate the effectiveness of teachers' participation in a mathematics networked learning community in terms of the learning environments created by these teachers in their classrooms in their respective schools, as well as their students' attitudes towards mathematics. For credibility in this study, statistical analyses were also carried out to validate the questionnaire assessing classroom learning environment and attitudes to mathematics when used with Primary 5 mathematics students in Singapore. Associations between students' perceptions of their classroom environment and their attitudes to mathematics were also investigated.

This chapter presents conclusions and implications based on pre–post changes in students' perceptions of the learning environment and attitudes towards mathematics as a result of teachers' participation in a mathematics networked learning community. Besides discussing the limitations of both the sample selection and the research methods used, it also suggests future research directions based on insights gleaned from this study. The various sections in this chapter are:

- Overview of the thesis (Section 5.2)
- Summary of results and discussion (Section 5.3)
- Significance and implications (Section 5.4)
- Constraints and limitations of the study (Section 5.5)
- Recommendations for future research (Section 5.6)
- Conclusions (Section 5.7).

5.2 OVERVIEW OF THE THESIS

This study was inspired by the professional development initiative in Singapore for building a teacher-led culture of professional excellence centred on the holistic development of the child. Networked learning community was identified as one of the enablers that encourage teachers to deepen their knowledge and skills through reflecting critically on their practice and engaging in dialogue on pedagogical ideas with teachers across schools. With this educational initiative to promote professional collaboration among teachers, it is therefore of interest to find out the impact of networked learning communities on students' learning. The main aims of this research study were to:

- investigate the validity and reliability of a learning environment and attitude questionnaire when used in primary mathematics classrooms in Singapore
- investigate relationships between attitudes towards mathematics and the learning environment
- evaluate the effectiveness of teachers' participation in a mathematics networked learning community in terms of their students' perceptions of the learning environment and attitudes towards mathematics.

This study used a pretest–posttest quasi-experimental design to compare the changes in classroom environment and attitudes of those classes whose teachers participated in a mathematics networked learning community with those classes whose teachers were not in networked learning community. To gather data from the students, five Primary 5 mathematics teachers from the same networked learning community were invited to participate in this research. Each of the five teachers was from a different school and each teacher arranged for another Primary 5 mathematics teacher in his/her respective school to participate in this study. The mathematics classes of teachers who were not in the networked learning community formed the comparison group for the study while the mathematics classes of teachers who were in the networked learning community formed the experimental group. Data were gathered from 375 Primary 5 students from 10 mathematics classes in five different schools through a questionnaire called the Mathematics Classroom Environment and Attitude Questionnaire (MCEA).

The instrument used to assess students' perceptions of their classroom learning environment included three scales from the What is Happening In this Class? (WIHIC) questionnaire and a newly-constructed scale. An attitude scale based on the Test Of Science-Related Attitudes (TOSRA) was used to assess students' attitudes towards mathematics. This instrument was first checked for its validity and reliability using the data gathered from the 375 Primary 5 mathematics students before the pretest and posttest data were used to investigate the effectiveness of teachers' participation in a networked learning community. Finally, associations between students' attitudes to mathematics and their perceptions of the classroom learning environment were investigated.

There are five chapters in this thesis and three research questions to drive my inquiry into the effectiveness of teachers' participation in a mathematics networked learning community in terms of students' perceptions of their classroom learning environment and attitudes towards mathematics. Chapter 1 outlined the background and educational significance of this study, its aims and its research questions. Chapter 2 presented a comprehensive literature review in areas related to this study, namely, networked learning community and learning environment. The first segment of the literature review highlighted the various meanings of learning community and the concept of networked learning community as a mode of professional development for teachers. This was followed by a discussion of the development of the field of learning environment, its history and validation of various instruments for measuring learning environments. In particular, the focus was on the WIHIC because scales for my study were chosen from this instrument. This chapter also gave an overview of the contributions of studies involving the WIHIC in various countries and in various languages. Chapter 2 concluded with a comprehensive review of literature devoted to the assessment of students' attitudes towards mathematics.

Chapter 3 on research methodology described the design and instruments used in my study, the samples and the statistical methods adopted for data analysis. The sample of the 375 students and ten teachers from five different schools was elaborated. This chapter provided details of the scales chosen from the WIHIC and TOSRA to form a questionnaire called the Mathematics Classroom Environment and Attitude (MCEA) questionnaire to measure changes in students' perception of their learning environment and attitudes to mathematics. It explained how the MCEA questionnaire was put together and piloted before it was used in the main study. The collection and analysis of the quantitative data were also described as follow:

- The internal structure of the 40 items in the learning environment and attitude scales based on the WIHIC and TOSRA was checked by separately subjecting the pretest and posttest data to principal axis factoring with varimax rotation and Kaiser normalisation. Factor analysis was conducted to determine whether the 40 items from the MCEA questionnaire measured four independent dimensions of the learning environment (Cooperation, Teacher Support, Involvement and Problem Solving) and one dimension of Enjoyment of Mathematics.
- The internal consistency reliability of the MCEA questionnaire was calculated using Cronbach alpha coefficient to indicate whether the items in each learning environment and attitude scales assess a similar construct.
- The ability of each learning environment scale to differentiate significantly between the perceptions of the students from the different classrooms was investigated with one-way ANOVA. The eta^2 statistic was calculated to determine the degree of association between class membership and the dependent variable for each of the learning environment scales.
- The bivariate relationship between the Enjoyment scale and each environment scale of the MCEA questionnaire was analysed with simple correlation.
- The joint influence of the whole set of environment scales on each attitude scale, as well as the identification of which of the four scales of the MCEA questionnaire contributed most to the multivariate associations between learning environment and student attitudes, were examined through multiple regression analysis. The standardised regression weight (β) was used to describe the association between a particular learning environment scale and enjoyment of mathematics when all other learning environment scales were mutually controlled.
- The effectiveness of teachers' participation in a mathematics networked learning community in this study was investigated by conducting one-way multivariate analyses of variance (MANOVA) with repeated measures for changes between pretest and posttest data in students' perceptions of the learning environment and attitudes for both the experimental and comparison groups.

- The magnitude of these differences between the pretest and posttest was determined by calculating the effect sizes (the difference between means expressed in standard deviation units).

Chapter 4 reported the results of analyses of the pretest and posttest data. Factor analysis results for learning environment and attitude scales for pretest and posttest were presented in Table 4.1. The scale mean, standard deviation, internal consistency (Cronbach alpha reliability) and the ability to differentiate between classrooms (ANOVA results) using data gathered through the questionnaire were reported in Table 4.2. The simple correlation and multiple regression analyses for associations between the learning environment and enjoyment scales for the pretest and posttest data were presented in Table 4.3. Finally, Table 4.4 reported the results of MANOVA with repeated measures and effect sizes separately for the comparison and experimental groups for pre–post changes for each learning environment and enjoyment scales.

This final chapter of my thesis not only summarises and discusses my study, but it also draws conclusions based on the results and proposes directions for future research. The limitations and significance of this research are also included in the discussions.

5.3 SUMMARY OF RESULTS AND DISCUSSION

The following subsections present a summary of the findings related to each of the research question for my study.

5.3.1 Results for Research Question 1

Research Question 1: *Are the learning environment scales based on the WIHIC and a newly-constructed scale and the attitude scale based on TOSRA valid and reliable when used with a sample of primary-school mathematics students in Singapore?*

To answer the first research question, concerning the reliability and validity of the questionnaire, various statistical analyses were conducted with the data collected from my sample of 375 Primary 5 mathematics students in Singapore. The pretest and posttest data from the MCEA questionnaire were analysed separately using principal axis factoring followed by varimax rotation and Kaiser normalization to check the factor structure of the questionnaire. The criteria for the retention of any item were that its factor loading must be at least 0.35 for its own scale and less than 0.35 for every other scale. There were a total of three items that did not meet the criteria and were therefore removed from the Problem Solving scale. From the original 40 items, 37 items were kept in the original 5-factor structure. Except for the Problem Solving scale which had five items only, the three scales from the WIHIC had eight items each. Likewise, the Enjoyment scale also had eight items.

The percentage of variance accounted for by the different MCEA scales ranged from 5.06% to 32.75% for the pretest data, whereas the range for the posttest data was from 3.37% to 36.13%. The total variance was 57.52% for pretest data and 57.57% for posttest data. The Enjoyment scale accounted for the most variance (32.75% for pretest data and 36.13% for posttest data). Eigenvalues associated with different factors ranged from 1.52 to 12.77 for pretest data and from 1.35 to 14.45 for the posttest data. The factor analysis results supported the factor structure of the 37-item questionnaire and attested to the independence of factor scores on the four learning environment and one attitude scales.

The alpha reliability coefficient for the different MCEA scales ranged from 0.85 (Cooperation) to 0.94 (Enjoyment) for the pretest and from 0.78 (Cooperation) to 0.94 (Enjoyment) for the posttest. These values suggest satisfactory internal consistency reliability for all the MCEA scales. The results therefore support the a priori structure and internal consistency and reliability of the MCEA questionnaire. The alpha coefficients from these data are very similar to those reported by Aldridge, Fraser and Huang (1999), which ranged from 0.85 to 0.90 with a sample of 1879 Grade 7–9 students from 50 classes in Taiwan.

The analysis of variance (ANOVA) results in the last column of Table 4.2 show that a significant difference (p<0.01) between the perceptions of students in different classes occurred for every scale. The eta^2 statistic ranged from 0.08 to 0.18 for the pretest and from 0.12 to 0.21 for the posttest data for the different scales. These results confirm the ability of the MCEA questionnaire to differentiate between students in different classes.

Generally, the results reported suggest that the learning environment scales based on the WIHIC and the attitude scale based on the TOSRA were valid and reliable when used with this sample of Primary 5 mathematics students in Singapore. They are also consistent with past research studies involving the WIHIC in various countries and in various languages such as the many studies listed in Table 2.3.

5.3.2 Results for Research Question 2

Research Question 2: *Are there associations between each of the four scales in the learning environment scales and a scale measuring students' enjoyment of mathematics?*

When associations between the learning environment and Enjoyment were investigated through simple correlation and multiple regression analyses, each of the four learning environment scales of the MCEA questionnaire was positively and significantly correlated with the Enjoyment scale. For the pretest, correlations ranged from 0.36 for Cooperation to 0.48 for Problem Solving. For the posttest, correlations ranged from 0.44 for Cooperation to 0.57 for Problem Solving.

The multiple correlation (R = 0.55 for pretest and R = 0.66 for posttest) between the set of four learning environment scales and Enjoyment was statistically significant for both the pretest and posttest data. Inspection of the regression coefficient revealed that Teacher Support and Problem Solving were significant independent predictors of Enjoyment for both pretest and posttest data when the other learning environment scales were mutually controlled.

Because all the relationships shown in Table 4.3 were positive, this study therefore replicates a positive link between students' attitudes to mathematics and the four aspects of learning environments assessed by the MCEA questionnaire. This study therefore replicates a large volume of past research around the world that has consistently revealed positive associations between students' attitudes and classroom environment dimensions (Fraser, 2012, 2014; Fraser, Aldridge & Aldolphe, 2010; McRobbie & Fraser, 1993; Ogbuehi & Fraser, 2007; Sebela, Fraser & Aldridge, 2004). Drawing on this association between attitudes to mathematics and students' perceptions of the learning environment, it is worthwhile for teachers to expend their energy on improving the learning environment as this is likely to lead to improved student outcomes (Fraser, 2007).

5.3.3 Results for Research Question 3

Research Question 3: *Does teachers' participation in a mathematics networked learning community make a difference in their classroom teaching in terms of their students' perceptions of their classroom learning environment and attitudes to mathematics?*

My third research question involved the effectiveness of teachers' participation in a mathematics networked learning community in terms of students' classroom environments and attitudes to mathematics. To answer this question, a one-way multivariate analysis of variance (MANOVA) with repeated measures was conducted separately for the experimental group and the comparison group. The four learning environment scales and the student outcome scale (Enjoyment) were the dependent variables and the testing occasion (pretest vs. posttest) was the independent variable. While the ANOVA results provided information about the statistical significance for educational importance, effect sizes were calculated to describe the magnitude of these differences in the pre–post changes.

Based on the statistical analysis presented in Table 4.4 and Figure 1, the pre–post changes in learning environment and Enjoyment scales for the comparison group were statistically nonsignificant for two scales (namely, Cooperation and Problem Solving), but statistically significant for the other three scales (Teacher Support, Involvement and Enjoyment). The pre–post changes for experimental group were statistically significant for every learning environment and Enjoyment scale. In terms of effect sizes, the pre–post changes for the comparison group were small in magnitude for four scales (ranging from 0.06 to 0.37 standard deviations) and moderate (0.45 standard deviations) for the scale of Involvement. For the experimental group, the effect sizes were moderate to large in magnitude for all scales; ranging from 0.45 for Teacher Support to 0.90 standard deviations for Problem Solving.

Generally, the pre–post changes were larger in magnitude for the experimental group than for the comparison group for every MCEA scale. These results suggest that teachers' participation in a mathematics networked learning community made a difference in their classroom teaching in terms of their students' perceptions of their classroom learning environment and attitudes to mathematics. It also provides empirical evidence that the practices that occurred during the networked learning community facilitated teachers in translating their professional learning into classroom teaching. In this collaborative learning model of professional development, teachers share their instructional strategies and learn with teachers from other schools. The network as described in Section 1.2.2.1 provides opportunities for teachers to articulate what they know (and what they need to know) and helps teachers to reflect on their teaching practices with fellow educators from diverse expertise. In this way, good practices such as use of Talk Moves and the ways to structure group work using co-operative learning strategies were disseminated across schools and were associated with changes in classroom learning environment and enjoyment in the mathematics classes in the experimental group.

5.4 SIGNIFICANCE AND IMPLICATIONS

In Singapore, although there are a number of studies contributing to a growing pool of learning environment research over the past decades (e.g. Chionh & Fraser, 2009; Chua, Wong & Chen, 2011; Goh & Fraser, 1998; Khoo & Fraser, 2008; Koh & Fraser, 2014; Peer & Fraser, in press; Quek, Wong & Fraser, 2005; Teh & Fraser, 1994, 1995; Wong & Fraser, 1996), there has been no study which was conducted in primary schools in Singapore to find out from younger students their perceptions of their mathematics classroom learning environment. My study is the first in the Singapore context that focused on the impact of teachers' participation in networked learning community on students' perceptions of their learning environment, and therefore this closed a gap in the literature as discussed in Section 2.5. This study reinforces findings from other research that participation in a network is linked to enhanced student outcomes (Earl et al., 2006).

The study of networked learning community is still considered as an emerging field relative to other research areas in education. So far, there have been only a few studies that examined the impact of network participation on student outcomes. My literature review highlighted a gap in Section 2.5 in that no prior research has employed a learning environment framework to investigate the effectiveness of participation in networked learning community in terms of the learning environments created. As such, my research not only adds to the existing body of knowledge about the influence of networked learning communities on student outcomes, but it also shows how learning environment scales could be used as process criteria to evaluate the impact of teachers' professional learning on their classroom practices and student outcomes. This is augmented by research in recent years which has confirmed that the classroom culture has considerable influence on the quality of student learning experiences (den Brok, Fisher, Rickards, & Bull, 2006; Fraser, 1998b).

Most past studies of the effectiveness of teachers' professional development are based on self-reports by teachers through reflection logs or interviews. Changes in students' perception of learning environment and attitudes towards learning depend on changes in instructional practices. These changes can emerge from professional learning and conceptual change that occurs through interaction among teachers within and across schools in networks (Earl et al., 2006). Therefore, changes in classroom behaviour are stronger indicators of the effectiveness of professional development programmes than workshop evaluation forms or surveys filled in by teachers. Analyses of data from the MCEA questionnaire indicate that there is potential in building teachers' capacity through networked learning community which facilitates the sharing and dissemination of effective teaching practices to provide a more favourable classroom environment for the learning of mathematics.

My study therefore supports the Singapore Ministry of Education's continuous effort in recognising the importance of learning communities for continual improvement and innovation in teaching and learning processes. Learning is most effective when teachers are encouraged to learn collaboratively and share their reflections, especially when the learning is focused on improving instructional practices (Darling-Hammond & McLaughlin, 2011). In a study on "Developing the Repertoire of Heuristics for Mathematical Problem Solving" in Singapore, it was suggested that, to promote engaged pedagogies for the teaching of mathematics, teachers need to work with other teachers, educators, and researchers to experiment with strategies that take cognizance of students' ways of solving problems (Wong & Tiong, 2006). Because building sustainable networked learning communities has been identified as a strategic lever for educational improvement in Singapore, my study could encourage the use of learning environment questionnaires such as the WIHIC as a basis for monitoring and improving teachers' own classroom environments.

My study also could encourage the Singapore Ministry of Education to embark on a large-scale study to replicate my finding that teachers' participation in networked learning communities promotes more positive learning environments and attitudes among students in other samples and in other subjects. As discussed in Section 2.5, this study fills a gap by providing the empirical evidence for the impact of network in terms of achieving more positive classroom learning environments which can lead to improved student outcomes.

Although there have been relatively few studies in the field of learning environments that focus on elementary school mathematics, this study has provided empirical evidence of the impact of teacher professional development on classroom environment in primary mathematics. It also supports the importance of promoting positive learning environments for improving student attitudes towards mathematics. The instrument used in this study was shown to be valid and reliable for a sample of primary school students (refer to Section 4.2).

Therefore, the MCEA questionnaire, which is modified from WIHIC and TOSRA, can be used with confidence by researchers and teachers to provide an economical assessment of students' perceptions of their classroom learning environment and their attitudes towards mathematics. In addition, because most of these questionnaires originated from the Western countries, the MCEA questionnaire, which taps into the nuances and uniqueness of Asian classrooms, can be considered as a worthwhile resource for investigating learning environments in the Asian context.

By validating a classroom learning environment questionnaire in Singapore, my study has contributed to the field of learning environments by filling a gap involving the lack instruments for use at the primary school level. Besides adding to the current stock of research on learning environments, the MCEA questionnaire is another resource for mathematics educators for gleaning insights into their classroom environments in order to inform the teaching and learning of mathematics.

5.5 CONSTRAINTS AND LIMITATIONS OF THE STUDY

Despite efforts taken to reduce the effects of potential limitations in this study, there were inevitable situations and factors that were beyond my control. Because of several limitations in my research, the following factors need to be considered when interpreting the finding from this study.

5.5.1 Representativeness and Size of Sample

Because of the timing of the data collection, as well as the level of interest of the teachers in starting a networked learning community during the time of my study, I decided to consider a networked learning community in which the teachers were all teaching classes of learners whose progress in mathematics was relatively low for that grade level in their respective schools. Therefore, all of my comparison students were of higher ability in mathematics than the students in the experimental group. This constraint led to the experimental group showing a lower pretest mean for all the scales and the comparison group showing a higher pretest mean for all the scales. This underlines the importance of my research design in which pre–post differences (rather than simply posttest scores) for two groups were compared.

In an empirical study in which the goal is to make inferences about a population from a sample, the size and representativeness of the sample are important considerations. A larger sample size is likely to give a more accurate result because there is less variance and it allows more powerful statistical significance testing. My sample size was limited to teachers from the same networked learning community who were interested in participating in this study. Because there were only eight members in this particular community, it was a challenge to get more than five teachers to volunteer for the study.

Besides the level of interest of the teachers, permission from the principals of these teachers was needed for data collection from the students in their schools. So, not only was the size of the sample a limitation in this study, but also its representativeness was restricted because of the constraints mentioned. Because of limits to my sample's representativeness, the generalizability of my findings also would be somewhat limited.

In future research, I recommend a sample that is both larger (to enhance the statistical power) and more representative (to improve generalizability of results). When determining the exact size of future samples, it is recommended that a statistical power calculation is conducted (Huck, 2012).

5.5.2 Duration of Study

By the time that I had obtained approval from the relevant authorities for the study, the earliest time for data collection was during Week 1 of Term 3 and for teachers to start their networked learning was in Week 2 of Term 3. Because of the national examinations for the Primary 6 students, which involve all primary school teachers in Singapore, the posttest data had to be collected by Week 3 of Term 4. Therefore, it was only possible for this study to run for about 12 weeks.

If the study had a longer timeframe, the results might have shown another picture concerning the effectiveness of teachers' participation in mathematics networked learning community in terms of students' perceptions of their learning environment and their attitudes towards mathematics. During this period of intervention, the teachers in the experimental group were very committed and the findings suggest that there was a change in their instructional practices which resulted in a more positive learning environment in their mathematics classrooms. It is not clear if this changed practice would be sustainable over a longer timeframe. The findings of my study should therefore be applied with caution to other groups. In recommending further research to be conducted for a period approaching one school year, I am also cognizant of the threats to validity, such as experimental mortality due to attrition of students or teachers. Another threat could be design contamination because there is a possibility that teachers in the comparison group also might start to adopt the teaching methods used by teachers in the experimental group or teachers in the experimental group might experience boredom with the approach.

5.5.3 Lack of Students' Achievement Data

In my study, I used only the MCEA questionnaire to provide criteria of effectiveness regarding students' perceptions of the classroom learning environment and their attitudes. Although numerous studies have established associations between the classroom learning environment and students' achievement among samples of different ages and in different subject areas (Fraser, 2007; Wubbels & Levy, 1993), student achievement in mathematics (in the form of a common pretest/posttest of mathematics concepts) might have been included to provide another criterion of the effectiveness of teachers' participation in a mathematics networked learning community.

5.5.4 Lack of Qualitative Data

My study involved only quantitative data obtained through students responding to the MCEA questionnaire; there were no qualitative data to help to explain the reasons for the pre–post changes in students' perceptions of their learning environment and attitudes towards mathematics. According to Tobin and Fraser (1998), learning environment research can be enhanced by using multiple research methods to provide both quantitative and qualitative data. They advocate the collection of both quantitative and qualitative data to obtain credible and authentic outcomes because the complexity of classroom learning environments creates the need for multiple modes of data collection. In my study, qualitative data were not collected because of the shortage of curriculum time associated with the many events and activities in Term 3 in the calendars of the Singapore schools. Originally, I had intended to conduct structured interviews with teachers, but this was not possible because only two teachers were available for the interview.

In some notable studies, qualitative methods such as interviews or reflective journals were used to triangulate quantitative data collected from the learning environment questionnaire. For example, Aldridge et al. (2012) used both quantitative and qualitative data in a case study of the extent to which action research based on students' perceptions of the learning environment was useful in guiding teachers' improvements in their classroom learning environments. A study that uses a variety of methods of data collection can lead to complementary insights and help to identify problems and possible solutions in the field of learning environments. Because qualitative data collection might have provided further insight into the statistically significant findings from the analyses of quantitative questionnaire data in this study, its absence therefore can be considered a potential limitation. To mitigate against this lack of qualitative data, a description of the networked learning activities is presented in Section 1.2.2.1 in order to shed some light on the quantitative findings.

5.5.5 Limitations to Statistical Analyses

Although the types of statistical analysis chosen for my research were quite adequate for my somewhat pioneering and exploratory study, perhaps more sophisticated analyses might have been considered. Having a larger sample size in future research would allow use of multilevel analysis. Also confirmatory factor analyses could be employed in addition to exploratory factor analyses in future studies.

5.6 RECOMMENDATIONS FOR FUTURE RESEARCH

Some of the successes of my study, together with its potential limitations as outlined in Section 5.5, naturally lead to suggestions for the following desirable directions for future research.

5.6.1 More Representative and Larger Samples

Future studies should involve larger and more representative samples of students. These students should be selected from a wider range of academic abilities in mathematics and from more schools and a variety of schools so as to obtain more statistically-powerful and more generalizable findings about the effectiveness of teachers' participation in mathematics networked learning communities.

It can be quite challenging to convince teachers to be involved in a study, especially if they have to enlist another teacher from their school to form the comparison group. To encourage more teachers from more networked learning communities to participate in future research, instead of using experimental–comparison groups as in my study, researchers could consider the use of actual–preferred forms to compare students' preferred and actual perceptions of their classroom learning environment. Assessing how close actual perceptions are to preferred perceptions of the learning environment could provide useful information about how the processes and the network engagements impact on classroom practices. Such information could enable policy-makers to make more evidence-based decisions for teacher professional development.

There are some studies that have used the actual and preferred forms to investigate the impact of an intervention on the classroom learning environment. With a sample of 978 secondary school students from Australia, Dorman (2008) compared scores on actual and preferred forms of WIHIC and found large difference between actual and preferred Cooperation. In Singapore, Chua et al. (2011) used actual and preferred forms to investigate teachers' and students' perceptions towards their Chinese Language classroom learning environments for a sample of 50 teachers and 1,460 Grade 9 students in 50 classes. They found that, although both Chinese Language teachers and students perceived their classroom learning environments positively, they would like improvements on all the six dimensions (Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Cooperation and Equity). They also found that female students perceived their actual and preferred classroom environments more positively than did their male counterparts.

5.6.2 Longer Duration of Study

Future studies should also span a longer period of time than the 12-week duration in my study. Reflecting on this research and taking into consideration the Singapore schools' calendar, a period of nine months would allow the pretest data to be collected at the beginning of the school year and posttest data to be collected in September (start of the national examination). This would help to determine whether my findings of pre–post changes in students' attitudes and perceptions of their learning environment are sustained over a period of almost a school year.

5.6.3 Inclusion of Students' Achievement

In my study, the criteria of effectiveness for evaluating networked learning community were pre–post changes in learning environment and student attitudes towards mathematics. In future research, student achievement in mathematics could be included in order to provide a deeper understanding of the impact of teachers' networked learning on student outcomes. This could be accomplished by conducting a common pretest and posttest of understanding of mathematical concepts across the sample being studied. This is in accordance with a view by Cohen and Manion (1994) who suggested that, if two measures are used and they agree, ‘convergent validity’ is strengthened.

5.6.4 Mixed-Methods Approach

A mixed-methods approach involving both quantitative and qualitative data could be adopted in future research to provide deeper insights into patterns that emerge from the quantitative data and to add credibility to the findings. Triangulation of quantitative data with qualitative data not only provides a more robust conclusion, but it also helps to elaborate and explain relationships drawn from statistical analyses. One of the considerations in using triangulation in future research would be to select triangulation sources with different biases and different strengths so that they can complement each other (Miles & Huberman, 1994). In situations when triangulations lead to inconsistent findings, one could weigh the evidence of the data and also to check the meaning of outliers.

Aldridge et al. (2012) used qualitative data from reflective journals, written feedback, forum discussions and interviews in conjunction with quantitative data collected through administering the COLES questionnaire to a sample of 2,043 students. The qualitative data were used to illuminate the processes used by teachers during action research and to examine more closely how one of the teachers used student responses to the learning environment questionnaire as a tool for reflection and as a guide in transforming her classroom environment.

Pickett and Fraser (2009) employed a multimethod approach when investigating the efficacy of mentoring programmes for beginning elementary school teachers. In their study with a sample of 7 teachers and 573 Grades 3–5 students, they used qualitative research methods (observations, interviews, focus-group discussions and reflective journal-keeping) to augment quantitative data (questionnaires, achievement tests, attitude surveys) to provide richer interpretations and insights into student and teacher outcomes from the mentoring programme. They found that information from students’ interviews was consistent with their perceptions as assessed by a modified WIHIC questionnaire. Comments from the students were also consistent with their responses to an attitude survey.

To capture student perceptions of their wider experiences in a place-based environment education setting that incorporates constructivist pedagogy, Zandvliet (2013) held a series of focus groups with teachers to clarify the specific constructs in the questionnaires and to refine the wording of individual survey items. So, when replicating my research in the future, qualitative data such as interviews with teachers and students and video-recording of teachers' engagement during the networked learning could be used to augment the quantitative data collected from the MCEA questionnaire.

5.6.5 Other Statistical Analyses

Besides investigating relationships between the Enjoyment of Mathematics and the various learning environment scales using correlation and multiple regression analyses which reveal linear relationships, different analyses could considered to examine the existence of any non-linear relationships. Exploratory factor analyses of the MCEA questionnaire could be supplemented with confirmatory factor analyses.

Overall, this study supports the desirability in future research of using learning environment variables as process criteria to evaluate the effectiveness of teacher professional development in terms of the quality of the classroom environments created by these teachers at their schools. Future replications of my research could focus on the relationships between teachers' perceptions of their learning environment in the networked learning community and their respective students' perceptions of their classroom learning environment. This could shed valuable light on how to provide high-quality professional development to help teachers to make connections between what has been taught during a professional development programme and how this is enacted in actual classroom practice.

5.7 CONCLUSION

Pickett and Fraser (2009, p. 1) highlighted that "the litmus test of the success of any professional development program is the extent of changes in teaching behaviours and ultimately student outcomes in the participating teachers' school classrooms". Based on this contention, my study of teachers' participation in a mathematics networked learning community is distinctive in that it drew on the field of learning environments in evaluating its effectiveness in terms of the participants' classroom teaching behaviours as assessed by their students' perceptions of their classroom environments. With the focus on the impact of professional development (networked learning) on changes in teaching behaviours (learning environment) and student outcomes (attitudes to mathematics) in the networked teachers' classrooms, I believe that my study has contributed to both fields of research.

This study represents one of the few applications of learning environment ideas in investigating the effect of teachers' involvement in networked learning community. In tandem with the changing educational landscape, there are more professional development efforts aimed at building teachers' capacity. Besides bringing parsimony to research, assessing the learning environment is reliable and provides a good indicator of the effectiveness of professional development initiatives. It is my hope that this study will be replicated on a much larger scale in order to guide improvements in classroom learning environments and to enhance student learning of mathematics in Singapore. It is also my wish that using a learning environment framework will become common when evaluating professional development programmes in Singapore.

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APPENDICES

The following appendices are included:

Appendix A: Mathematics Classroom Environment and Attitude Questionnaire

Appendix B: Teacher Participant Information Sheet

Appendix C: Student Participant Information Sheet

Appendix D: Parent/Guardian Information Sheet

Appendix E: Teacher Participant Consent Form

Appendix F: Student Participant Consent Form

Appendix G: Parent/Guardian Consent Form

Appendix H: Principal Permission Letter.

Appendix A

Mathematics Classroom Environment and Attitude (MCEA) Questionnaire

Directions for Students

These questionnaires contain statements about this mathematics class. You will be asked your opinion about these statements.

There are no 'right' or 'wrong' answers. Your opinion is what is wanted. Think about how well each statement describes what this class is like for you.

Draw a circle around

1	if this statement is true	**Almost Never**
2	if this statement is true	S**eldom**
3	if this statement is true	**Sometimes**
4	if this statement is true	**Often**
5	if this statement is true	**Almost Always**

Be sure to give an answer for all questions. If you change your mind about an answer, just cross it out and circle another.

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

Practice Example

Suppose you were given the statement "I choose my partners for group discussion." You would need to decide whether you feel that this statement is true; 'Almost Never', 'Seldom', 'Sometimes', 'Often' or 'Almost Always'. If you select '**Often**', then you would circle the number **4** on your questionnaire.

Your Name: ______________________________

Register Number: ______________________________

Teacher's Name: ______________________________

School: ______________________________

Primary: ______________________________

Gender: Male / Female (please circle)

Items 1-24 in this questionnaire are from the What Is Happening In this Class? (WIHIC, Fraser, Fisher & McRobbie, 1996) and Items 33-40 are based on items selected from the Test of Science Related Attitudes (TOSRA, Fraser, 1981). These scales and items were used in my study and included in this thesis with the permission of their authors.

COOPERATION		Almost Never	Seldom	Some-times	Often	Almost Always
1.	I cooperate with other students when doing mathematics activities or work.	1	2	3	4	5
2.	I share my books and resources with other students when doing mathematics work.	1	2	3	4	5
3.	When I work in groups in this mathematics class, there is teamwork.	1	2	3	4	5
4.	I work with other students on projects in this mathematics class.	1	2	3	4	5
5.	I learn from other students in this mathematics class.	1	2	3	4	5
6.	I work with other students in this mathematics class.	1	2	3	4	5
7.	I cooperate with other students on mathematics activities.	1	2	3	4	5
8.	Students work with me to achieve class goals in mathematics.	1	2	3	4	5
TEACHER SUPPORT		**Almost Never**	**Seldom**	**Some-times**	**Often**	**Almost Always**
9.	The teacher takes a personal interest in me.	1	2	3	4	5
10.	The teacher goes out of his/her way to help me.	1	2	3	4	5
11.	The teacher considers my feelings.	1	2	3	4	5
12.	The teacher helps me when I have trouble with mathematics problems.	1	2	3	4	5
13.	The teacher talks with me.	1	2	3	4	5
14.	The teacher is interested in my problems.	1	2	3	4	5
15.	The teacher moves about the class to talk with me.	1	2	3	4	5
16.	The teacher's questions help me to understand.	1	2	3	4	5
INVOLVEMENT		**Almost Never**	**Seldom**	**Some-times**	**Often**	**Almost Always**
17.	I discuss ideas in class.	1	2	3	4	5
18.	I give my opinions during class discussions.	1	2	3	4	5
19.	The teacher asks me questions.	1	2	3	4	5
20.	My ideas and suggestions for solving mathematics problems are used during classroom discussions.	1	2	3	4	5

INVOLVEMENT		Almost Never	Seldom	Some-times	Often	Almost Always
21.	I ask the teacher questions.	1	2	3	4	5
22.	I explain my ideas for solving mathematics problems to other students.	1	2	3	4	5
23.	Students discuss with me how to go about solving mathematics problems.	1	2	3	4	5
24.	I am asked to explain how I solve mathematics problems.	1	2	3	4	5
PROBLEM SOLVING		**Almost Never**	**Seldom**	**Some-times**	**Often**	**Almost Always**
25.	I know the steps that my teacher takes to solve a mathematics problem.	1	2	3	4	5
26.	I can figure out the steps needed to solve a mathematics problem.	1	2	3	4	5
27.	I know what questions to ask myself to solve a mathematics problem.	1	2	3	4	5
28.	I know how to self-correct when I make a mistake in mathematics.	1	2	3	4	5
29.	I explain how I solve a mathematics problem to my classmate.	1	2	3	4	5
30.	I receive feedback from my classmate on the way I solve a mathematics problem.	1	2	3	4	5
31.	I use feedback to improve the way I solve a mathematics problem.	1	2	3	4	5
32.	I know the steps that my classmate takes to do a mathematics problem.	1	2	3	4	5
ENJOYMENT		**Almost Never**	**Seldom**	**Some-times**	**Often**	**Almost Always**
33.	Mathematics lessons are fun.	1	2	3	4	5
34.	I like mathematics lessons.	1	2	3	4	5
35.	School should have more mathematics lessons each week.	1	2	3	4	5
36.	I look forward to mathematics lesson.	1	2	3	4	5
37.	Mathematics is one of the most interesting school subjects.	1	2	3	4	5
38.	Mathematics lessons are time well-spent.	1	2	3	4	5
39.	I put effort into mathematics work.	1	2	3	4	5
40.	I would enjoy school more if there were more mathematics lessons.	1	2	3	4	5

Appendix B

Curtin University
Science and Mathematics Education Centre

Teacher Participant Information Sheet

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

Purpose of Research
I am investigating the effect of teachers' participation in a mathematics networked learning community on students' perceptions of their classroom environment and attitudes to mathematics in 5 primary schools in Singapore.

Your Role
I am interested in comparing data obtained from students whose teachers participate in networked learning and data obtained from students whose teachers do not participate in networked learning with the purpose of assessing students' classroom environment and attitudes amongst Primary 5 students. You will be asked to administer a survey (pre-survey in June and post-survey in September) to your students during one of your class periods. This process will take approximately 30 minutes.

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

Confidentiality
The information collected will be kept separate from your or your students' personal details, and only my supervisor and I will have access to this. The questionnaire will be kept in a locked cabinet for five (5) years and after which, they will be destroyed.

Further Information
This research has been reviewed and given approval by the Curtin University Human Research Ethics Committee (Approval Number XXXXXX) and MOE Data Admin Office (Approval Number XXXXXX). If you would like further information about this study, please feel free to contact me at cynthia_seto@moe.gov.sg or 6664 1441. Alternatively, you may contact my supervisor, Professor Barry J. Fraser, at B.Fraser@curtin.edu.au.

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

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

Appendix C

Curtin University
Science and Mathematics Education Centre

Student Participant Information Sheet

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

Purpose of Research
I am investigating the effect of teachers' participation in a mathematics networked learning community on students' perceptions of their classroom environment and attitudes to mathematics in 5 primary schools in Singapore.

Your Role
I am interested in comparing data obtained from students whose teachers participate in networked learning and data obtained from students whose teachers do not participate in networked learning with the purpose of assessing students' classroom environment and attitudes amongst Primary 5 students. You will be asked to complete a survey (pre-survey in June and post-survey in September) that will be administered during one of your class periods. This process will take approximately 30 minutes.

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

Confidentiality
The information you provide will be kept separate from your personal details, and only my supervisor and I will have access to the questionnaires you complete. These questionnaires will be kept in a locked cabinet for five (5) years and after which, they will be destroyed.

Further Information
This research has been reviewed and given approval by the Curtin University Human Research Ethics Committee (Approval Number XXXXXX) and MOE Data Admin Office (Approval Number XXXXXX). If you would like further information about this study, please feel free to contact me at cynthia_seto@moe.gov.sg or 6664 1441. Alternatively, you may contact my supervisor, Professor Barry J. Fraser, at B.Fraser@curtin.edu.au.

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

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

Appendix D

Curtin University

Curtin University
Science and Mathematics Education Centre

Parent/Guardian Information Sheet

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

Purpose of Research
I am investigating the effect of teachers' participation in a mathematics networked learning community on students' perceptions of their classroom environment and attitudes to mathematics in 5 primary schools in Singapore.

Your Child's Role
I am interested in comparing data obtained from students whose teachers participate in networked learning and data obtained from students whose teachers do not participate in networked learning with the purpose of assessing students' classroom environment and attitudes amongst Primary 5 students. Your child will be asked to complete a survey (pre-survey in June and post-survey in September) that will be administered during one of his/her normal class periods. This process will take approximately 30 minutes.

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

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

Further Information
This research has been reviewed and given approval by the Curtin University Human Research Ethics Committee (Approval Number XXXXXX) and the MOE Data Admin Office (Approval Number XXXXXX). If you would like further information about this study, please feel free to contact me at cynthia_seto@moe.gov.sg or 6664 1441. Alternatively, you may contact my supervisor, Professor Barry J. Fraser, at B.Fraser@curtin.edu.au.

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

Appendix E

Curtin University

Curtin University
Science and Mathematics Education Centre

Teacher Participant Consent Form

- I understand the purpose and procedures of the study.
- I have been provided with a *Teacher Participant Information Sheet*.
- I understand that the study itself may not benefit me.
- I understand that my involvement is voluntary and that I can withdraw from participating at any time without penalty or problems.
- I understand that no personal identifying information, such as my name and address, will be used in any published materials.
- I understand that all information related to this study, including audio recordings and transcripts of the audio-recordings, will be securely stored for a period of five (5) and after which, it will be destroyed.
- I have been given the opportunity to ask questions about this research.
- I agree to participate in the study outlined to me.

____

____
Name (Print)

____
Signature

____
Date

____
School

Appendix F

Curtin University

Curtin University
Science and Mathematics Education Centre

Student Participant Consent Form

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

____

____
Name (Print)

____
Signature

____
Date

____
Student Register Number

____
School

Appendix G

Curtin University

Curtin University
Science and Mathematics Education Centre

Parent/Guardian Consent Form

Dear Parent/Guardian:

Permission is requested for ____ to participate in a teacher-based research study. The purpose of the research is to investigate the effect of teachers' participation in a mathematics networked learning community on students' perceptions of their classroom environment and attitudes to mathematics. The entire process will take approximately 30 minutes.

The contact will be non-intrusive and will not disrupt classroom lessons. **The student samples will not be identifiable and confidentiality of all participants will be maintained.**

Participation in this study will be beneficial in providing intellectual insights on how teacher professional development may impact classroom learning environment and attitudes for improved learning outcomes in mathematics amongst primary school students in Singapore.

Please indicate below whether you give permission for the above named student to participate in this valuable research study. Forms should be returned to the students' mathematics teacher.

I will be the individual responsible for this research. Should you have any questions, feel free to contact me at 6664 1441 or via e-mail at cynthia_seto@moe.gov.sg
.

Sincerely,

Cynthia Seto, Master Teacher (Mathematics)

____YES, permission is GRANTED to participate. **____No, permission is DENIED to participate.**

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

Appendix H

Curtin University

Curtin University
Science and Mathematics Education Centre

Principal Permission Letter

Dear Principal,

My name is Cynthia Seto and I am currently working on my doctoral degree with Curtin University in Perth, Western Australia. I wish to request permission for selected teachers and students in your school to participate in a teacher-based research study. The purpose of the research is to investigate the effect of teachers' participation in a mathematics networked learning community on students' perceptions of their classroom environment and attitudes to mathematics in 5 primary schools in Singapore.

I would like to administer classroom environment and attitudinal surveys during the months of June and September 2012.

Student participants will be asked to be involved in the completion of a survey. The entire process will take approximately 30 minutes. The contact will be non-intrusive and will not disrupt classroom lessons. The student samples will not be identifiable and confidentiality of all participants will be maintained.

Participation in this study will be beneficial in providing intellectual insights on how teacher professional development may impact classroom learning environment and attitudes for improved learning outcomes in mathematics amongst primary school students in Singapore.

Included in this correspondence are copies of my approval letters from the MOE Data Admin Office (Approval Number XXXXXX) and Curtin University's Human Research Ethics Committee (Approval Number XXXXXX).

I will be the individual responsible for this research. Should you have any questions, feel free to contact me at 6664 1441 or via e-mail at cynthia_seto@moe.gov.sg. Alternatively, you may contact my supervisor, Professor Barry J. Fraser, at B.Fraser@curtin.edu.au.

Best regards,

Cynthia Seto
Research Investigator, Curtin University