Science and Mathematics Education Centre

Use of Exchange-of-Knowledge Method for Enhancing Classroom Environment and Students' Attitudes and Achievements in Mathematics

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DECLARATION

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

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ABSTRACT

The main aim of this study was to evaluate the relative effectiveness of the exchange-of-knowledge method (a teaching approach that offers all students in a group an equal opportunity to interact with one another on the learning tasks and to communicate their ideas in various ways) and traditional teaching methods in terms of classroom learning environment, student attitudes toward mathematics and student achievement in mathematics. Another purpose of this research was to validate suitable measures of classroom environment and students' attitudes toward mathematics. A third aim was to investigate associations between students' outcomes (attitudes and achievement) and their perceptions of the classroom learning environment.

The sample consisted of 490 grade 6–8 students attending a middle school and 22 grade 5 students attending an elementary school in Georgia. Classroom environment was assessed using a refined version of the What Is Happening In this Class? (WIHIC) questionnaire to assess students' perceptions of Cohesiveness/Cooperation, Teacher Support, Task Orientation, and Equity, whereas attitudes were assessed with a refined version of the Test of Science Related Attitudes (TOSRA), in which items were modified by changing the word 'science' to 'mathematics', assessing Attitude to Mathematical Inquiry and Enjoyment of Mathematics Lessons.

Factor and reliability analyses revealed that a refined four-scale 25-item version of the WIHIC and a refined 17-item version of the attitude questionnaire exhibited sound factorial validity and internal consistency reliability. Also all four WIHIC

scales differentiated significantly between the perceptions of students in different classrooms.

Implementation of the exchange-of-knowledge method was found to have a positive impact. For the four classroom environment and two attitude scales, the control group experienced pretest-posttest changes that were both statistically nonsignificant and small in magnitude (ranging from 0.01 to 0.10 standard deviations). In contrast, the exchange-of-knowledge group experienced pretest-posttest changes on these six classroom environment and attitude scales that were statistically significant and large in magnitude (ranging from 0.63 to 3.12 standard deviations).

Third, a series of simple correlation and multiple regression analyses revealed positive and statistically significant associations between students' attitudes and the nature of the classroom environment. With the student as the unit of analysis, students' attitudes were more positive on both scales (Attitude to Mathematical Inquiry and Enjoyment of Mathematics Lessons) in classrooms with greater Cohesiveness/Cooperation, Teacher Support, Task Orientation, and Equity.

My research represents one of relatively few studies that have utilized learning environment dimensions in evaluating elementary school mathematics programs, as well as the first study to evaluate the exchange-of-knowledge method using a learning environment framework. The practical implication of my study for other mathematics educators is that the exchange-of-knowledge method has the potential to promote positive classroom environments and student attitudes among elementary-school students.

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RATIONALE FOR THE STUDY

1.1 Introduction

Although mathematics often is considered a subject that is misunderstood by many and understood by only a gifted minority, it should be accessible to all students – those who are bright and those who struggle. Mathematics education should engage students in educational experiences that help them to make sense of mathematics and to recognize and assess the power of their own mathematical thinking.

As we engage in the twenty-first century, educators in the USA strive to increase mathematics achievement scores. Norm-referenced achievement test used in the state of Georgia, such as the Iowa Test of Basic Skills (ITBS) and the Georgia Criterion Reference Test (CRCT), indicate that students often lack an understanding of mathematical concepts. Although students must become prepared to be competitive in a global society, some students at the elementary, middle-grade and secondary levels find it difficult to understand mathematics. Students should understand the importance of mathematics and realize that they can utilize their knowledge of mathematics to make sense in everyday situations. Neidorf, Binkley, Gattis, and Nohara (2006) recount that, in the USA, 15-year-olds ranked 27th out of 39 countries that participated in the 2003 Program for International Student Assessment (PISA) (OECD, 2003, 2004) achievement testing, which assessed students' ability to apply mathematical concepts to real-world problems.

Friedman's (2005) *The World is Flat* stressed that both the globalization of the work force and changes in business models will eventually weaken the American workforce and lower the country's standard of living. How can adults in the USA be competitive when they lag behind most of their counterparts in science and mathematics as students? There is a need for all citizens to be mathematically literate in order to be competitive nationally and internationally in business and to be successful in a global technological society. According to Partnership for 21st Century Skills (2003), there is a great need in the USA to improve the mathematics curriculum.

Typically, mathematics instructors try to cover too much content and too many skills, which leads to confusion and to students not mastering mathematical skills. In the case of the National Council of Teachers of Mathematics (NCTM, 1989) standards, quantity is not the same as quality. The irony of the Third International Mathematics and Science Study (TIMSS) is patently clear: although USA mathematics textbooks attempt to address 175% more topics than do German textbooks and 350% more topics than do Japanese and German students, Japanese and German students significantly outperformed American students in science achievement as well mathematics (Schmidt, McKnight, & Raizen, 1996).

Battista (1999) has acknowledged that the economic costs of the traditional system of mathematical miseducation are staggering. According to the National Research Council (1989), 60% of college mathematics enrollments are in courses ordinarily taught in high school, and the business sector spends as much on remedial mathematics education for employees as is spent on mathematics education in schools, colleges, and universities combined. This is a cry for reform of mathematics curricula and instruction. In the research reported in this thesis, I investigated the effectiveness of one innovative approach to the teaching of mathematics (namely, the exchange-of-knowledge method).

This chapter provides a rationale and an introduction for the present study under the following headings:

- Purposes of the study (Section 1.2)
- Mathematics education in Georgia (Section 1.3)
- Historical perspectives on the field of classroom learning environments (Section 1.4)
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1.2 Purposes of the Study

My study followed the long traditions of assessing classroom learning environments using questionnaires that tap students' perceptions, of evaluating educational programs in terms of the impact of the classroom environment, and of investigating associations between classroom environment and student outcomes (namely, attitudes and achievement) (Fraser, in press).

My first research objective involved the validation of the questionnaire used in my study.

Research Question # 1

Are modified versions of widely-applicable instruments for assessing classroom environment and attitudes to mathematics valid when used among elementary and middle-school students in Georgia:

a. What Is Happening In this Class? (WIHIC)
b. Test of Mathematics Related Attitudes (TOMRA)?

In past research, the exchange-of-knowledge method has yielded some positive results in terms of student achievement and attitudes toward mathematics (Leikin & Zaslavsky, 1999). Therefore my study further investigated the effectiveness of using the exchange-of-knowledge method, but my research was unique because it included learning environment criteria.

Research Question # 2

Is the exchange-of-knowledge method more effective than traditional teaching methods in terms of:

a. classroom learning environment
b. student attitudes toward mathematics
c. student achievement in mathematics?

Past research, which is reviewed in the next chapter, has shown that positive classroom environments usually are linked to positive attitudes to mathematics and better mathematical achievement. Using modified versions of the What Is Happening In this Class? (WIHIC) and Test of Mathematics Related Attitudes (TOMRA), I investigated the strength of the associations between classroom environment and the student outcomes of attitudes and achievement.

Research Question # 3

Are there associations between students' outcomes (attitudes and achievement) and their perceptions of the classroom learning environment?

1.3 Mathematics Education in Georgia

Because my study was conducted in the state of Georgia in the USA, this section provides some contextual details about mathematics education in that state. The staff at Joseph Martin Elementary (JME), one of the schools at which I conducted my research, aspires to accommodate each student's academic needs. The educational staff members at JME are highly motivated to achieve this goal and they utilize research results and achievement test scores as a guide to improve education.

The No Child Left Behind Act (2001) first was passed by the Johnson administration as the Elementary and Secondary Act. It was then revised as part of its last major revamp in 2001 during the President George W. Bush administration. The National Science Foundation (NSF) was part of President Bush plan with the responsibility of developing, implementing, and managing a mathematics and science partnership initiative.

The No Child Left Behind Act was a comprehensive agenda for enhancing students' achievement and success and for bridging the academic gap for all. Included in the reform package was a call for partnerships between institutions of higher education and K−12 schools in an attempt to increase the quality of mathematics and science education in elementary and secondary schools. The type of partnership activities addressed in the No Child Left Behind Act involve making mathematics and science curricula more rigorous, enhancing mathematics and science professional development, attracting more mathematics and science majors to teaching, and aligning high-school mathematics and science standards. Because the initial proposal did not produce the intended outcome, another revision was undertaken.

In his State of the Union address, President Obama claimed that Congress should reform the No Child Left Behind law based on the principles that have guided Race to the Top. The old No Child left Behind had several flaws, including teachers teaching to the test and subjects such as science and history not being taught, which was hurting children instead of helping them.

President Obama proposed a comprehensive revamping of the law that would give confidence to states to elevate academic principles, end the classifying of reasonably supervised schools as failing, and divert energies away from turning around the few thousand schools that are in the worst shape and towards helping states to find more efficient ways of assessing the work of administrators and educators.

The revised No Child Left Behind Act calls on states to accept new academic standards that involve all students in being prepared for college and careers by the time when they leave high school. This plan would replace the current 2014 time limit for bringing all students in the USA to an academically-proficient level.

The Obama administration proposed that the No Child Left Behind law focus on letting the states, schools and teachers come up with innovative ways to give children skills to prepare them for jobs for the future. Therefore, the Obama administration would like to reduce the emphasis on measuring each student's academic growth, regardless of the performance level at which he/she starts.

The USA spends an estimated $120 billion a year overall for grades K−12 education. Yet, American students' performance on the Third International Mathematics and Science Survey (TIMSS) lagged behind their international counterparts in both mathematics and science. Furthermore, in the 10 years since the results of the first study were released, the significant attention directed toward science and mathematics education has not resulted in the expected improvement in student performance. Nor has it led to a significant increase in the numbers of American students pursuing higher education degrees and ultimately careers in science, mathematics, or engineering (Schmidt, McKnight & Raizen, 1996).

Several underlying principles have been referred to as contributing to this national failure to guide children toward excellence in science and mathematics (NCTM, 1989). These include too many teachers teaching out of field, inadequate teacher preparation in the areas of science and mathematics, too few schools with challenging mathematics and science curricula and textbooks, too few students taking advantage of advanced coursework, and a lack of understanding about how students learn and about classroom practices. Partnerships between colleges and universities and K−12 school systems have a role in addressing each of these deficiencies.

Georgia lawmakers sent a powerful message to educators when they stipulated that the state's schools must teach all students and that no child or group can be left behind. Many educationalists did not want business leaders and lawmakers interfering in their field. Educators debated whether the rules of business necessarily apply to education and warned that the state could be headed for serious trouble. Nevertheless, business voices were heard (Anderson & Davenport, 2002).

Emerging from this reform was a school rating system based chiefly on scores from the Georgia Criterion Reference Test (CRCT), a series of tests in reading, writing, mathematics and science administered annually to students in Grades 1, 2, 3, 4, 5, 6, 7, and 8. Presently, students who do not pass the CRCT in Grade 3, 5, and 8 are not promoted to the next grade level. Instead, they are given another opportunity to pass the test during the summer. As of August 2004, no students are exempted from taking the CRCT. A formula based on the CRCT scores, attendance records, withdrawals, academic yearly gains, and academic yearly improvements are used to determine whether a school's own report card is classified as excellent, above excellent, satisfactory, below satisfactory, or failing.

Educators in the Liberty County Board of Education (LCBOE) hope that strategies aimed at reducing the differences between the USA and other countries in students' achievement test scores will be successful. The county needed to move its students from memorization and pattern recognition (rote and observational levels of understanding) to the how and why (insightful) and the formal levels of understanding (Buxton, 1978).

According to the U.S. Census Bureau 2010, Hinesville is a small transit urban city in Liberty County, Georgia. Fort Stewart Army installation is located in Liberty County and covers almost half of Liberty County (Liberty County Economic Snapshot, 2004). Together, Hinesville and Fort Stewart encompass the Hinesville-Fort Stewart area. Many of the students attending schools in Liberty County are associated with the military.

In 1999, about 15% of the county's population lived below the poverty level. Furthermore, 19.2% of children under the age of 18 years lived below the poverty level in Liberty County. The 2000 Census reported that 11.1% of Liberty County's households were headed by females with children under 18 years of age, relative to 9.0% statewide. Households with children under 18 years old represented 50.5% of all households in Liberty County. The county per capita personal income in 2004 was only $21,471, compared to $29,782 for Georgia and $33,050 for the USA. Therefore, students' poor attitudes toward mathematics, high transit rates, and low social-economic status the students help to explain lower achievement.

1.4 Historical Perspectives on Field of Classroom Learning Environments

My study drew on and contributed to the field of learning environments. Early studies of human environments go back over seven decades to Lewin's (1936) human behavior model and Murray’s (1938) needs-press model. The belief that discrete human environments exist was recognized as early as the 1930s, when Lewin (1936) acknowledged that the environment and its interactions with personal characteristics of the individual are determinants of human behavior. Following Lewin’s work, Murray (1938) proposed a Needs-Press Model in which situational variables in the environment account for a degree of behavioral variance.

Fraser (1981) proposed a simple approach by which teachers can use information obtained from classroom environment questionnaires to guide attempts to improve classrooms. Fraser (1994, 1998a) stated that some teachers are reluctant to take time from teaching to attempt to create stimulating and positive classroom learning environments, yet research shows that positive learning environments are linked to improved student outcomes.

A historical look at the field of the learning environment over the past few decades shows that a striking feature is the availability of a variety of economical, valid and widely-applicable questionnaires for assessing student perceptions of classroom
widely-applicable questionnaires for assessing student perceptions of classroom
environments (Fraser, 1998a, 1998b). These instruments include the Individualized Classroom Environment Questionnaire (ICEQ) for open or individualized setting (Fraser, 1990), the Science Laboratory Environment Inventory (SLEI) for laboratory classroom settings (Fraser, Giddings & McRobbie, 1995), the College and University Classroom Environment Inventory (CUCEI) for higher-education classrooms (Fraser & Treagust, 1986), the Questionnaire on Teacher Interaction (QTI) for assessing the interpersonal relationships between teachers and students (Wubbels & Levy, 1993), the Constructivist Learning Environment Survey (CLES)

for assessing the degree to which a particular classroom environment is consistent with constructivist epistemology (Aldridge, Fraser, Taylor, & Chen, 2000; Taylor, Fraser & Fisher, 1997), and the Culturally Sensitive Learning Environment Questionnaire (CLEQ) developed by Fisher & Waldrip (1997) for assessing cultural differences between students' perceptions of classroom environment in different countries. The My Class Inventory was designed for younger students and for students with low reading levels as it has simple language (Fisher & Fraser, 1981; Fraser, Anderson & Walberg, 1982; Fraser & O'Brien, 1985). These questionnaires are reviewed more in detail in my literature review chapter (Chapter 2).

However some of the questionnaires overlap in what they measure and contain items that might not be pertinent in contemporary classroom settings. Therefore, in my study, I chose the What Is Happening In this Class? (WIHIC) questionnaire (Fraser, Fisher, & McRobbie, 1996). A main benefit of the WIHIC is that it combines salient scales from past questionnaires with new scales assessing dimensions of contemporary relevance. Literature relevant to the WIHIC is reviewed extensively in Chapter 2.

Kajander (1999) claims that children at the elementary level are naturally creative and that it is wonderful to watch their enthusiasm as they discover new concepts on their own. He believed, too, that more importance on creative aspects of mathematics would allow students to enjoy mathematical activities more. Fraser (1998a) recommends that teachers should strive to create productive classroom learning environments which emphasize more organization, cohesiveness, and goal direction and less friction. Fraser (1998a) considers that learning environment assessments should be used in addition to student learning outcome measures to provide information about subtle, but important, aspects of classroom life. The evaluation of innovations, new curricula, and restructuring efforts should include classroom environment assessments to provide process measures of effectiveness (Lightburn & Fraser, 2007; Moar & Fraser, 1996; Teh & Fraser, 1994). In my study involving an evaluation of the exchange-of-knowledge method, the learning environment was used as a major criterion of effectiveness (in addition to the student outcomes of attitudes and achievement).

1.5 Exchange-of-Knowledge Method

My research involved evaluating the use of the exchange-of-knowledge method among Grade 5−8 mathematics students in a transit area in Hinesville, Georgia. The exchange-of-knowledge method is a cooperative learning method. In addition to promoting academic achievement, cooperative learning also has been found to influence students' attitudes toward students with disabilities, their self-esteem and social acceptance, and their teachers' ratings of students with disabilities (Putnam, Markovchick, Johnson, & Johnson, 1996). Cooperative learning has also been used as a vehicle to guide and shape student behavior (Johnson, & Johnson, 1975).

In the exchange-of-knowledge method, the primary objectives of the mathematics activities are to offer all students in a group an equal opportunity to interact with one another on the learning tasks and to encourage them to communicate their ideas in various ways (Good, Mulryan, & McCaslin, 1992). In my study, the exchange-of-knowledge method was evaluated in terms of students' perceptions of their classroom learning environment, students' attitudes towards mathematics, and achievement in mathematics.

Students were paired within a larger group of four students. Each student was required to explain to his or her partner how to solve the mathematics worked-out example for which the student had gained expertise on the previous card and to listen to the explanations given by the partner about how to deal with the worked-out example on a new card. Each student was required to solve a problem similar to the previous worked-out example that the student's partner explained to the student and, if needed, could ask for help in solving it from the partner who already had tackled the problem. After students completed the work on a pair of cards, they changed partners within the group in order to give each group member an opportunity to act in the role of both a student and a teacher. Each card consisted of two or three parts. Part 1 consisted of the worked-out example, with the extent of the explanations on the card depending on the students' level and their learning experience on the topic. Part 2 included a problem similar to the worked-out example on the first part of the card for students' individual solutions. If appropriate, Part 3 included an additional problem to be solved by more-advanced students. For each study card, a corresponding homework card also was available. The learning setting was divided into groups of experts and groups for exchange-of-knowledge.

With the No Child Left Behind Act, the State of Georgia Department of Education has placed emphasis on improving its standardized test scores. Therefore, this study can potentially provide practical and important information to educators. This research could provide information to guide the implementation of the exchange-of-knowledge method and the creation of learning environments that encourage cooperation and collaboration within the classroom. According to Leiken and Zaslowsky (1999), the exchange-of-knowledge method is extremely effective in teaching mathematics. Also, the exchange-of-knowledge method has been found to be effective in terms of increased academic achievement in experimental studies conducted with students (Leikin & Zaslavsky, 1997 & 1999; Tanişli & Sağlam, 2006).

In Leikin and Zaslavsky's (1997) study, when the students' learning in traditional settings was compared with their learning when using the exchange-of-knowledge method, it was found that the experimental small-group cooperative-learning setting facilitated a higher level of learning activities. Also classroom observations indicated an increase in students' activeness. Altogether, students spent much more time actively involved in the experimental cooperative setting. Leikin and Zaslavsky (1999) attributed this change to an increase in mathematical communications, which were defined in general as student-student and student-teacher interactions related to the learning material.

The exchange-of-knowledge method enables teachers to facilitate students' mathematical communication. Observations leading to these communicative interactions take the form of giving an explanation and posing a question or requesting help. These two types of communicative interactions, which are called mathematical communication, fall into what Webb (1991) calls students' verbal interactions. In the NCTM's Curriculum and Evaluation Standards for School Mathematics (1989), mathematical communications play an important role in learning mathematics. When communicating mathematically, students usually enhance their understanding of the concepts being taught, establish shared understanding of mathematics, learn in a comfortable environment, assist the teacher in gaining insight into their thinking, and become more active learners.

However Tanişli and Sağlam (2006) reported no statistically significant differences in the performance of students who received instruction through the exchange-of-knowledge method and those who were taught using a teacher-centered learning method, except at the recall level.

1.6 Significance of Study

There are several reasons why my study about the effectiveness of the exchange-of-knowledge method is important and unique. First, mathematics educators value students who have positive perceptions of their classroom environments and display positive attitudes to mathematics. These mathematic educators envisage that such students not only perform well in their school years in this particular subject, but also continue with further studies in some area of mathematics. Subsequently, this could help students to make vital, meaningful contributions, be competitive nationally and internationally in business, and be successful in a global society.

The second reason why this study is unique is that it could assist teachers to become aware of the specific classroom environment factors that promote students' attitudes and achievement in mathematics.

The third reason why I undertook this study was its uniqueness as the first study of the exchange-of-knowledge method that focused on student perceptions of the classroom learning environment and their attitudes to mathematics (although Tanisli and Saglam, 2006, evaluated this method in terms of student achievement).

The present study could provide vital information concerning the learning environments in my school district as there have been hardly any studies undertaken in this district. For example, because my study involved validating a widely-applicable learning environment instrument, the WIHIC (Fraser, Fisher, & McRobbie, 1996), this questionnaire could be used in future research and by other researchers and teachers to measure a number of aspects of the learning environment.

1.7 Conclusion and Overview of Thesis

If mathematics teaching is to be successful in Georgia and nationally and if students are to be competitive in business and in a technologically-based society, then it is of vital importance that students in elementary, middle-grade, secondary, and higher levels of education have positive perceptions of their classroom environments. In turn, eventually this can lead to improved attitudes and achievement in mathematics.

The present study attempted to answer some important questions about the exchange-of-knowledge method. One of the objectives of this study was to ascertain whether widely-applicable instruments used for assessing classroom environment and attitudes to mathematics are valid when used among elementary and middle-school students in Georgia. The second objective was to evaluate whether the exchange-of-knowledge method is more effective than traditional teaching methods (involving an emphasis on rote learning and content coverage rather than understanding and problem-solving) in terms of classroom learning environment, student attitudes toward mathematics and student achievement in mathematics. The third objective involved associations between students' outcomes (attitudes and achievement) and their perceptions of the classroom learning environment.

My research could provide valuable information about the learning environment in my school district as there have been very few studies previously carried out in Georgia. The study used a modified form of a valid and widely-applicable learning environment instrument, the WIHIC (Fraser, Fisher, & McRobbie, 1996), to measure a number of aspects of the learning environment. The results of the research could help to identify environmental factors that could affect students' attitudes and achievement in mathematics. This study adds to the field of learning environments as it is one of only a few that has used learning environment perceptions as process criteria in the evaluation of educational innovations in mathematics.

In addition to delineating the aims and significance of this study, this introductory chapter has provided details of my study's context, especially mathematics education in Georgia, the field of learning environments, and the exchange-of-knowledge method.

Chapter 2 reviews literature pertaining to the field of the classroom learning environment, the exchange-of-knowledge method, and students' attitudes to mathematics. Chapter 3 describes research the methods used in the present study and gives reasons for the choice of my sample of elementary students. Chapter 4 provides a detailed reporting of the analyses and results of the study. Chapter 5 presents the conclusions to this study while, at the same time, pointing out both its limitations and suggesting future lines of research.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

The major goal of the current study was to evaluate the effectiveness of the use of the exchange-of-knowledge method among Grade 5–8 mathematics students in Georgia. In the exchange-of-knowledge method, the primary objective of the mathematics activities is to offer all students in a group an equal opportunity to interact collaboratively with each other on appropriate tasks that encourage them to communicate their ideas in various ways. In this research, the exchange-of-knowledge method was evaluated in terms of students' perceptions of their classroom learning environment, students' attitudes toward mathematics, and students' achievement in mathematics. Classroom environment was assessed using a modified version of the What Is Happening In this Class? (WIHIC) questionnaire, whereas attitudes were assessed with items selected from the Test of Mathematics Related Attitudes (TOMRA).

This chapter reviews literature relevant to the present study under six sections:

- Traditional and Constructivist Mathematics Instruction (Section 2.2)
- Cooperative Learning and Exchange-of-Knowledge Method (Section 2.3)
- Field of Learning Environments (2.4)
  - Instruments Used for Assessing Classroom Learning Environments (2.4.1)

- Learning Environment Inventory (2.4.1.1)
- Classroom Environment Scale (2.4.1.2)
- Individualized Classroom Environment Questionnaire (2.4.1.3)
- My Class Inventory (2.4.1.4)
- College and University Classroom Environment Inventory (2.4.1.5)
- Questionnaire on Teacher Interaction (2.4.1.6)
- Science Laboratory Environment Inventory (2.4.1.7)
- Constructivist Learning Environment Survey (2.4.1.8)

- What Is Happening In this Class? (WIHIC) (2.4.2)
  - Development and Characteristics of WIHIC (2.4.2.1)
  - Validation of WIHIC in Western Context (2.4.2.2)
  - Validation of WIHIC in Asian Context (2.4.2.3)
  - Questionnaires Based on WIHIC: OBLEQ, TROFLEI and COLES (2.4.2.4)

- Students' Attitudes Toward Mathematics (2.5)
- Chapter Summary (2.6).

2.2 Traditional and Constructivist Mathematics Instruction

The study of mathematics has existed for at least as long as recorded history. Through the years, mathematics has changed and its effect on culture has been complex. During the past few centuries, mathematics has progressed from its status as a separate field of scholarly endeavor and is essentially a middle twentieth-century phenomenon (Braddon, Hall & Taylor, 1993).

Changes took place rapidly in the agricultural age and up to the technologically-based age. However, the economic arena is improving while mathematics education has become relatively stagnant. Robinson (1992) stated that student individual abilities, along with society's outlook, have been altered, despite the fact that long-established methods and modes of teaching are still practised by a large number of educators.

Prestigious organizations, such as the National Council of Teachers of Mathematics (NCTM, 1989, 1991, 2000), the National Research Council (NRC, 1989) and the National Governors Association Center for Best Practices (2010) agreed upon the needed changes in the mathematics classroom instruction in order to enhance mathematics instruction and promote student success. There is a need to strengthen the connections between mathematics and students' real-world situations.

Another shift is from conventional teaching methods, involving memorizing procedures and facts, to a hands-on model, in which students actively contribute to their learning process. McNair (2000) declares that both of these reform efforts are supposed to change students' roles in the classroom from dependent learners to independent learners.

Advocates of mathematics education reform have argued that conventional mathematics instruction, the established form of instruction in most American schools, has not met the needs of students for mathematics that provides a transition to real-life contexts. Battista (1999, p. 426) asserts that: "For most students, school mathematics is an endless sequence of memorizing and forgetting facts and procedures that make little sense to them." A primary concern is to promote active participation in mathematics learning among student (Ross, 1996). Some traditional classroom teaching involves rote and memorization skills as opposed to concrete and abstract skills. Current teaching techniques do not always encourage the high levels of academic understanding or reasoning, problem-solving, and communication skills that students will need to be competitive in this global and technological society (Silver & Stein, 1996).

Conventional mathematics is based on educational opinions and practices which essentially differ from those encouraged by the present reform attempts, and teachers dispute that classroom educators wishing to alter their ideas must first experience personally the alternative teaching approaches (Schifter & Fosnot, 1993).

The National Council of Teachers of Mathematics (NCTM) Standards has called for reform in USA school mathematics programs in order to prepare all students to be competitive in a global society (National Council of Teachers of Mathematics, 1989, 1991, 1995, 2000; National Research Council, 1989). It is important that students are more actively engaged in order to promote higher levels of thinking, problem-solving, and understanding of mathematical procedures. Convincing a traditional teacher-centered educator to change to a student-centered approach is a difficult task, but it is attainable. This outdated concept of learning as a passive process often has dominated what counts as genuine work in school (Duit & Treagust, 1998).

Traditional whole-group instruction frequently involves students in identifying or recalling information. Traditionally, teachers place emphasis on rote learning and the application of facts and procedures. Although the same topics can be taught and retaught year after year, students do not necessarily comprehend them. In the traditional classroom, educators teach too much subject matter and cover too many skills, leading to confusion and students not mastering the skills. Existing teaching approaches do not generate the high levels of theoretical understanding or the reasoning, problem-solving, and communication skills that students need to be competitive in a global society (Silver & Stein, 1996). Numerous research studies have shown that traditional modes of instruction in mathematics are ineffective and seriously impede the development of students' mathematical interpretation and problem-solving skills (Battista & Larson, 1994).

Schifter (1996) confirms that numerous educators have taught mathematics in this fashion and that many diligent mathematics educators still use this approach to teaching today. Because the teaching of mathematics does not involve the integration of conceptual and procedural knowledge, experts are concerned that children do not make connections between mathematics and real-life experiences. Therefore, a major focus of the exchange-of-knowledge method used in my study was the relevance of mathematics to students' everyday out-of-school experiences. Subsequently, educators who have phobias about mathematics themselves can influence students also to have phobia about mathematics (Whitin & Wilde, 1992).

Undeterred by the large costs of the traditional system of mathematical miseducation, American schools carry on with this standard. The National Research Council (1989) asserts that 60% of college mathematics students need to undertake remedial classes based on what was taught in high school before being able to undertake courses in college mathematics. Also the business sector spends just as much on corrective mathematics education for its staff members as is spent on mathematics education in schools, colleges, and universities combined (Battista, 1999). Mathematical ignorance is seriously impeding the economy in a competitive and increasingly technological and global society. Battista (1999) points out that, in spite of this mathematics miseducation, the only time when Americans are made aware of mathematics teaching is when educators attempt to change it. Clearly, fallacies about mathematics and mathematics learning are so deeply rooted in society that most people can't comprehend potential improvements and so they typically dread and oppose change.

The irony of the Third International Mathematics and Science Study (TIMSS) is that, while USA mathematics books cover 175% more subject matter than do German textbooks and 350% more subject matter than do Japanese course books, both German and Japanese students considerably exceed USA students in mathematics achievement (Schmidt, McKnight, & Raizen, 1996). A possible solution for the USA would be to decrease the amount of content being covered.

There is disagreement among teachers, parents, administrators, and school boards concerning mathematics education. What are their concerns? Ross (1996) claims that there has been a decline in mathematical skills. While it is easier for educators to gauge and spot deficiencies in skills than in understanding, this deterioration is easily overstated. Nevertheless, this dilemma is important because future scientists, engineers, and mathematicians must acquire both considerable understanding and confidence in their skills.

The constructivist approach facilitates students in creating their own understanding of the subject matter from their prior knowledge. The primary idea of constructivism is that it provides a logical and essential framework for understanding and translating experiences of learning and teaching (Tobin & Tippins, 1993, p. 7). Constructivist principles are linked to the exchange-of-knowledge method (a focus of my study) in that students construct their own knowledge. Students are actively learning and the teacher is facilitating students' learning. Von Glasersfeld (1989) states that many mathematics educators agree that knowledge is not established passively but is actively constructed by students. Active learning is the foundation of the constructivist principle. In a constructivist teaching-learning procedure, the students and the teacher are active learners. The teacher is learning about the students' mathematical ability and, in the process, reforming his or her own mathematical understanding. Self-reflexivity is another strategy of constructivism, which refers to the fact that constructivists apply the doctrine of constructivism in their own activities (Steier, 1995).

Vygotsky's (1987) theory is one of the foundations of constructivism and shows the importance of social and motivational influences in giving rise to social constructivism. His theory has three themes – that social interaction plays a fundamental role in the process of cognitive development; that a student learns best from a more knowledgeable other; and that learning occurs when the student is in a zone of proximal development (i.e. when the learning is within reach of the student).

Vygotsky's theory promotes learning contexts in which students play an active role in learning and the teacher collaborates with the students to help to facilitate students' meaningful construction of knowledge. Learning therefore becomes a reciprocal experience for students and the teacher (Wertsch & Sohmer, 1995).

Within a constructivist approach, knowledge not only is personally created, but it is also socially mediated (Prawat, 1993; Taylor, 1993). The focal point of mathematics education research today is basically the student rather than the teacher. The constructivist outlook involves students actively creating their own knowledge whenever they learn skills. Learning is a process in which prior knowledge is activated to enhance newly-acquired knowledge through instruction and the classroom environment. Nevertheless, learning is not based only on what teachers present, but also is an interactive result of what information is encountered and students' prior knowledge (Allen & Fraser, 2007; Duit & Treagust, 1998).

Research has shown that students' existing knowledge is a major component in any academic activity. In the constructivist view, learning is conceptualized as a method of conceptual change in which someone makes sense of new information by using his or her existing knowledge. Conceptual change is a learning method in which people alter their ideas by capturing new ideas or existing ideas, or by exchanging existing ideas for new ideas (Hewson, 1981, 1982).

Learning mathematics constantly requires the method of conceptual change, more than the method of conceptual growth, which transpires throughout the period following conceptual change, when new links can be made. Theoretical growth is defined as broadening one's conceptual network, with concept change arising when one grows displeased with what is and becomes willing to acknowledge a new way of doing things (Duit & Confrey, 1996).

One way to elicit the different views of students is to have the teacher start teaching the subject matter with a non-graded quiz that is answered individually; the questions should take account of a range of choices that represent different responses. In teaching for conceptual change, students' different views must be elicited, students' views might have to change, and such teaching is metacognitive. The notion of metacognition refers to knowledge in relation to one's own cognitive processes and products. This kind of teaching is complete when the teacher, students, and the classroom environment take on features that maintain teaching for conceptual change (Hewson, 1996).

2.3 Cooperative Learning and Exchange-of-Knowledge Method

As we begin the twenty-first century, schools are undergoing major evolution in their mathematics agendas – transitions that involve fundamental changes in curricular content, modes of instruction, teacher education, professional development, methods of assessments, and public attitudes (National Research Council, 1989).

According to Davidson (1990a), it is hard to accurately describe cooperative learning because of the large diversity in the settings for facilitating cooperative learning and the differences between them. Cooperative learning encompasses any classroom learning setting in which students of all academic ability levels work together in a structured group toward a shared or common goal. Cooperative learning is the instructional use of small groups so that students work together to take full advantage of their own and each other's learning. Johnson and Johnson (1999) claim that it is broadly used in many fields and at different levels. The instructional use of small groups is important for the exchange-of-knowledge method to be effective.

The general idea, which lies beneath all cooperative learning techniques, is that students work together to learn and are accountable for one another's learning as well as their own (Slavin, 1990). One essential reason for its wide use could be the existence of research findings about its positive effect on academic achievement, peer relations, inclusion of children with special needs, self-esteem, attitudes and anxiety (Johnson & Johnson, 1981, 1989; Leikin & Zaslavsky, 1997; Sharan, 1980; Tarim, 2003; Tarim & Artut, 2004). It has been recognized that, because students must exclusively depend on careful listening, they are motivated to support and show interest in one another's work.

Johnson, Johnson and Smith (1991) synthesized over 375 studies of the effect of cooperative, competitive and individualistic efforts on student achievement and productivity. They found that students in cooperative learning settings performed better than students in either competitive or individualistic settings. They also noted that cooperative learning "resulted in more high-level reasoning, more recurrent generation of new ideas and solutions (i.e., process gain), and greater transfer of what is learned within one situation to another (i.e., group-to-individual transfer) than did competitive or individualistic learning" (p. 12).

Several cooperative learning methods are utilized in elementary-education and secondary-education courses. One technique developed by Leiken and Zaslowsky (1999) acknowledges the exchange-of-knowledge method. This learning approach shares some characteristics with the Jigsaw Method (Aronson et al., 1978) in that it gives students an opportunity to play the role of a teacher and to offer explanations to their peers. On the other hand, the exchange-of-knowledge method also allows students to work individually when appropriate. Also, the tasks are designed so that students work in pairs to ensure that every student has the opportunity to both study and teach each type of learning material.

The exchange-of-knowledge method meets the goals suggested by Good, Mulryan and McCaslin (1992) by giving students an opportunity to gain experience with some learning material and to explain it to others. This method was developed on the basis of guidelines for cooperative learning in mathematics classrooms according to Arthipova and Sokolov (1988).

Tanişli and Sağlam (2006) claim that cooperative learning is a method which provides effective and long-lasting learning. Cooperative learning is a broad term for various small-group interactive instructional procedures in which students work together on an academic task in small groups to help themselves and their teammates learn together (Millis, 1996).

The exchange-of-knowledge setting resembles some features of Slavin's (1987) team-assisted individualization program, which fosters students' individual work within larger groups and encourages them to check and help each other when necessary. However, the exchange-of-knowledge method has the potential to develop more intricate problem-solving and explaining activities. All students have to clarify to one another mathematical thoughts and principles, figure out for themselves how to solve problems, and decide on suitable or correct answers (Leiken & Zaslowsky, 1999).

The method of grouping students is very important. With few exceptions, research results support student groupings which are heterogeneous with regard to academic achievement, gender, ethnicity, task orientation, capability, and learning style. According to Davidson (1990b), the heterogeneity of a small group can be one of the most important issues when planning a cooperative learning setting. According to several researchers, students learn better in heterogeneous groups of different ability levels (Davidson, 1990a, 1990b; Slavin, 1985).

Leikin and Zaslavsky (1997) found that most students like receiving help from others or like working within groups. In their study, some students replied that complex concepts or difficult problems become easier when they learn mathematics by using cooperative learning. Part of the rationale for promoting performance could be that students obtain help through discussion to create peer support and expand deep thinking and perspectives with their group members. Mulryan (1994) also acknowledges that cooperative small groups for mathematics instruction have a strong emphasis on exploration, collaboration, and active participation, which do not often appear in traditional mathematics classrooms. These activities are likely to benefit all students' achievement because they provide more equal opportunities for students to engage in thinking and problem solving (Mulryan, 1994).

Based on Artzt and Newman (1990) and Sutton (1992), there are four necessary conditions that together constitute a cooperative learning setting:

- Students learn in small groups with two to six members.
- Students are engaged in learning tasks which require that students mutually and positively depend on one another and on the group's work.
- The learning environment provides all members of the group with an equal opportunity to interact with one another regarding the learning tasks and encourages them to communicate their ideas in various ways (e.g. verbally).
- Each member of the group has a responsibility to contribute to the group's work and is accountable for the learning progress of the group.

A cooperative learning setting needs to have all of the above conditions. Contrary to common belief, forming groups in the classroom is not sufficient for creating a genuine cooperative learning setting. Of the four conditions, the third is particularly significant according to Bishop (1985), Clement (1991), and Jaworski (1992).

Research results suggest that cooperative learning instruction can promote mathematics achievement in treatment groups relative to control groups using traditional learning. Other researchers also reported similar findings for mathematics students at different grade levels (3–12) and for different subjects (geometry and pre-calculus); see Berg (1993), Jacobs, Watson, Sutton, and Jones (1996), Nichols and Hall (1995), Mevarech (1985), Pratt and Moesner (1990), and Sherman (1986). These studies revealed that those students who worked with cooperative learning had superior mathematics performance relative to control groups in the same setting. These findings emphasized the benefits for students' learning of using cooperative learning methods in mathematics instruction.

Tanisli and Saglam (2006) confirm that research using the exchange-of-knowledge method demonstrated positive results at the knowledge level for students who received instruction with this method relative to those experiencing the traditional whole-group method. According to Leikin and Zaslavsky (1999), implementation of the exchange-of-knowledge method promoted students' active explorations in the mathematics classroom, mathematics communication, and positive attitudes.

2.4 Field of Learning Environments

The field of learning environments, which underpinned my study, has been placed into historical perspective in several past literature reviews (Dorman, 2002; Fisher & Khine, 2006; Fraser, 1986, 1994, 1998a, 2002, 2007, in press; Fraser & Walberg, 1991). Learning environment assessments have been used as dependent and independent variables in past research. An important triumph within the field has been the productive combination of quantitative and qualitative research methods (Tobin & Fraser, 1998).

Research has compellingly shown that attention to classroom environment is likely to pay off in terms of improving student outcomes (Fraser, 2001). Students spend a vast amount of time at school. Jackson's (1968) *Life in Classrooms* estimate that this is about 7000 hours by the end of elementary school. The title of Rutter, Maugham, Mortimore, Outson and Smith's (1979) book *Fifteen Thousand Hour* suggests that this figure rises to 15,000 hours by the completion of secondary school. As a result, students certainly have great interest in what happens to them at school. Students' reactions to and perceptions of their educational experiences are important.

The educational process involves not only curricular concerns and achievement, but also how the classroom environment affects the manner in which students learn science and mathematics (Fraser, 1989). An understanding of students' perceptions of their relationships with fellow students or teachers can provide insight into what students learn and how they accomplish various levels of proficiency in various content areas. Particular interests within the field of learning environments include assisting teachers to improve the environments of their classrooms and the impact of learning environments on students' cognitive and affective learning outcomes (Fraser, in press).

Literature reviews (Fraser, 1998a, 2007, in press) show that science education researchers have led the world in the field of classroom environment over the previous several decades, and that this particular field has provided understanding which can guide improvements in science education. Studies which built on Lewin's (1936) influential field theory and Walberg's (1981) theory of educational productivity have established that students' perceptions of the classroom psychosocial environment are related to their affective, behavioral, and cognitive learning (Fraser, 1986, 1994, in press; Fraser & Fisher, 1982b; Haertel, Walberg & Haertel, 1981). Fraser's (1994) tabulation of 40 past studies shows that past research into outcome-environment relationships has involved a variety of cognitive and affective outcome measures, a multiplicity of classroom environment instruments, and samples ranging across numerous countries and grade levels (Fraser, 1998a, in press; Majeed, Fraser & Aldridge, 2002).

Traditionally, research and evaluation in classrooms have relied heavily on academic outcomes. While the measurement of the outcomes is educationally important, research has indicated that the nature of the classroom environment also can affect students' affective and cognitive outcomes (Haertel, Walberg & Haertel, 1981). Over the past three decades, there has been considerable progress in the conceptualization and assessment of various aspects of the classroom environment, as well as the use of these assessments in a variety of different types of research (Fraser, 1998a, in press).

In the past few decades, the field of classroom environment has progressed to the point at which researchers and teachers can assess classroom environment and recognize its effects on students. This research has given teachers a deeper understanding of how individuals learn, the difficulties of teaching, and the structure of the classroom environment. An association between improved student attitudes and positive classroom environments has been consistently established, with students also achieving more when there is a positive classroom environment (Fraser, 1998a).

Walberg's (1981) multi-factor model of educational productivity includes the psychosocial learning environment as one of nine influences on student learning. This model proposes that learning is a function of student age, ability, and motivation; the quality and quantity of schooling; and the psychosocial environments of the home, the classroom, the peer group and the mass media. In a research synthesis (Fraser, Walberg, Welch, & Hattie, 1987; Walberg, 1986) and using secondary analyses of large databases collected as part of the National Assessment of Educational Achievement (Walberg, Fraser, & Welch, 1986), classroom environment and school environment were found to be strong predictors of both students' achievement and attitudes, even when a wide-ranging set of other factors in the productivity model was held constant.

To aid teachers' application of these methods and ideas, Fraser and Fisher (1986) created shorter versions of the actual and preferred forms of several classroom environment instruments and proposed procedures for improving classrooms. These procedures involve: first, assessment of student perceptions of actual and preferred environments; second, reflecting on discrepancies between actual and preferred environments; third, initiating interventions to reduce those discrepancies; and, fourth, assessment of actual environments after the interventions to determine if changes have occurred. These environment change studies have proved promising in research in Australia (Aldridge & Fraser, 2008; Fisher, Fraser & Bassett, 1995; Fraser & Fisher, 1986; Yarrow, Millwater & Fraser, 1997), England (Thorp, Burden & Fraser, 1994), South Africa (Aldridge, Fraser & Sebela, 2004) and the USA (Moss & Fraser, 2001; Sinclair & Fraser, 2002).

Educational learning environments can be considered as the social-psychological contexts or determinants of learning (Fraser, 1994). This interest in human environments is also shared to some extent by researchers in other fields including psychology, sociology, physiology, and engineering (Knirk, 1992; Vasi & Laguardia, 1992; Weinstein, 1979).

Because the existence of a wide array of useful and extensively-validated questionnaires is a hallmark of the field of learning environments (Fraser, 1998b), Section 2.4.1 provides a comprehensive review of these instruments.

2.4.1 Instruments for Assessing Classroom Learning Environments

The advancement of the field of learning environments has seen the development of numerous instruments that can be used to assess the classroom learning environment. Many of these instruments have been modeled after Moos's (1974) initial work and, as a consequence, a common theme runs through numerous instruments. Moos's three basic types of dimensions for classifying human environments are *Relationship Dimensions* (which identify the nature and intensity of personal relationships within the environment and assess the extent to which people are involved in the environment and support and help each other), *Personal Development Dimensions* (which assess basic directions along which personal growth and self-enhancement tend to occur) and *System Change Dimensions* (which involve the extent to which the environment is orderly, has clear expectations, maintains control and is responsive to change).

This section describes eight widely-used classroom learning environment instruments that follow Moos's three basic types of dimensions: Learning Environment Inventory, LEI (Section 2.4.1.1); Classroom Environment Scale, CES (Section 2.4.1.2); Individualized Classroom Environment Questionnaire, ICEQ (Section 2.4.1.3); My Class Inventory, MCI (Section 2.4.1.4); College and University

Classroom Environment Inventory, CUCEI (Section 2.4.1.5); Questionnaire on Teacher Interaction, QTI (Section 2.4.1.6); Science Laboratory Environment Inventory, SLEI (Section 2.4.1.7); and Constructivist Learning Environment Survey, CLES (Section 2.4.1.8). A brief overview of these eight widely-applicable classroom learning environment instruments is displayed in Table 2.1. The table shows the name of each scale, the grade level for which each instrument is suited, the number of items contained in each scale, and the classification of each scale according to Moos's (1974) scheme for classifying human environments.

The What Is Happening In this Class? (WIHIC) questionnaire is the most widely-used classroom learning environments instrument today. Although the WIHIC is included in Table 2.1, it is discussed in much more detail in a separate section (see Sections 2.4.2 for detailed information about the development, characteristics, and validation of the WIHIC). A separate section is devoted to the WIHIC because it was the learning environment instrument selected for and used in my study.

2.4.1.1 Learning Environment Inventory (LEI)

The initial development of the historically-significant LEI began in the late 1960s in conjunction with the evaluation and research related to Harvard Project Physics (Walberg & Anderson, 1968). The original version of the LEI evolved from Walberg's (1968) Social Climate Questionnaire. The final version of the LEI contains 105 statements with seven descriptors of typical school classes. The student expresses a degree of agreement or disagreement with each statement by choosing from four responses (Strongly Disagree, Disagree, Agree, and Strongly Agree). In addition, to reduce response bias for the respondent, some items are negatively phrased. A typical question in the Cohesiveness scale is “All students know each other very well”.

Table 2.1 Overview of the Nine Classroom Environment Instruments (LEI, CES, ICEQ, MCI, CUCEI, QTI, SLEI, CLES and WIHIC) and Their Scales Classified According to Moos’s Scheme

Instrument	Level	Items per Scale	Scales Classified According to Moos’s Scheme		
			Relationship	Personal Development	System Maintenance
Learning Environment Inventory (LEI)	Secondary	7	Cohesiveness Friction Favoritism Cliqueness Satisfaction Apathy	Speed Difficulty Competitiveness	Diversity Formality Material Environment Goal Direction Disorganization
Classroom Environment Scale (CES)	Secondary	10	Involvement Affiliation Teacher Support	Task Orientation	Order and Organization Rule Clarity Teacher Control Innovation
Individualized Classroom Environment Questionnaire (ICEQ)	Secondary	10	Personalization Participation	Independence Investigation	Differentiation
My Class Inventory (MCI)	Elementary	6–9	Cohesiveness Friction Satisfaction	Difficulty Competitiveness	
College and University Classroom Environment Inventory (CUCEI)	Higher Educatoin	7	Personalization Involvement Student Cohesiveness Satisfaction	Task Orientation	Innovation Individualization
Questionnaire on Teacher Interaction (QTI)	Secondary or Elementary	8–10	Leadership Understanding Helpful/ Friendly Student Responsibility and Freedom Dissatisfied Admonishing Uncertain Strict		
Science Laboratory Environment Inventory (SLEI)	Upper Secondary or Higher Education	7	Student Cohesiveness	Open-Endedness Integration	Rule Clarity Material Environment
Constructivist Learning Environment Survey (CLES)	Secondary	7	Personal Relevance Uncertainty	Critical Voice Shared Control Investigation	Student Negotiation
What Is Happening In this Class? (WIHIC)	Secondary	10	Student Cohesiveness Teacher Support Involvement	Investigation Cooperation	Equity Task Orientation

Adapted from Fraser (1998a)

2.4.1.2 Classroom Environment Scale (CES)

Another historically-significant questionnaire, the CES, developed by Rudolf Moos at Stanford University, is based on social climate scales created as part of a comprehensive set of perceptual measures of a variety of human environments, including psychiatric hospitals, prisons, university residences, and work environments (Fisher & Fraser 1983; Moos, 1974, 1980; Moos & Trickett, 1974, 1987). The original version of the CES consisted of 242 items representing 13 conceptual dimensions (Trickett & Moos, 1973). The final published version contains 90 items (9 scales with 10 items in each of the scales) with a True–False response format for each item. A typical question in the Teacher Support scale is "The teacher takes a personal interest in the students". Some CES items are negatively-worded and reverse-scored.

2.4.1.3 Individualized Classroom Environment Questionnaire (ICEQ)

While the LEI and CES set the ground work for the development of other classroom environment questionnaires, they do not include dimensions that distinguish individualized classrooms from conventional ones. Therefore, the ICEQ was developed to assess the learning environment of individualized classrooms as distinct from conventional ones. For example, Personalization and Participation dimensions were included as components of the ICEQ. The initial long version of the ICEQ (Rentoul & Fraser, 1979) was developed after interviewing teachers and secondary-school students. Afterwards, selected experts, teachers and junior high school students reviewed the questionnaire in draft form and provided suggestions for modifying it to become a shorter version containing 50 items (10 items in each of five scales) that are answered using a five-point frequency response format with the alternatives of Almost Never, Seldom, Sometimes, Often, and Very Often. To avoid biased responses from respondents, some items are negatively phrased. A typical question in the Personalization scale is “Different students use different books, equipment and materials”.

2.4.1.4 My Class Inventory (MCI)

The MCI is a simplified version of the LEI for use among children aged 8–12 years (Fisher & Fraser, 1981; Fraser, Anderson, & Walberg, 1982; Fraser & O’Brien, 1985; Majeed, Fraser & Aldridge, 2002). The MCI was developed for the elementary-school level because of its simplicity in wording, but also it has found its niche at the junior high school level, especially with students who have limited reading skills in English. The MCI contains 38 items in five scales with a two-point (Yes–No) response format and it includes some reverse-scored items. However, Fraser and O’Brien (1985) developed an even shorter version with 25 items. A typical question in the Friction scale is “Children are always fighting with each other”. Also, in a study in Singapore, Goh and Fraser (1998) used a three-point response format (Seldom, Sometimes, and Most of the Time) with the MCI.

Majeed, Fraser and Aldridge (2002) investigated lower-secondary mathematics classroom learning environments in Brunei Darussalam and their association with students’ satisfaction with learning mathematics. The study utilized a sample of 1565 students from 81 classes in 15 government secondary schools. A version of the My Class Inventory (MCI), which had been modified for the Brunei context, was administered to assess students' perceptions of the classroom learning environment. The study revealed a satisfactory factor structure for a refined three-scale version of the MCI assessing Cohesiveness, Difficulty and Competition. This finding is noteworthy because the factorial validity of the MCI had not previously been established in past research in other countries. In addition, each scale revealed satisfactory internal consistency reliability, discriminant validity and differentiated between the perceptions of students in different classes.

The My Class Inventory (MCI) was administered to a sample size of 588 Grade 3–5 students in Texas to evaluate student perceptions of classroom environment and the effectiveness of instruction using a textbook, science kits, or a combination of both. The study revealed sound factorial validity and reliability for the MCI and suggested that the use of science kits was associated with a more positive learning environment in terms of student satisfaction and cohesiveness. Higher student satisfaction was also found in the classrooms with greater cohesiveness and less friction and competition (Scott Houston, Fraser & Ledbetter, 2008).

In a small-scale evaluation of a K–5 mathematics program that integrates children's literature called Project SMILE (Science and Mathematics Integrated with Literature Experiences), Mink and Fraser (2005) used the MCI, attitude scales and qualitative methods among a sample of 120 Grade 5 mathematics students in Florida. The implementation of SMILE was found to have a positive impact in that there was congruence between students' actual and preferred classroom environment.

Sink and Spencer (2005) modified the MCI and used it as an accountability tool among elementary-school counselors and a sample of 2,800 elementary-school students in the USA. The revised short form of the MCI exhibited satisfactory reliability and factorial validity. Overall this psychometric study showed the MCI to be valid and reliable.

2.4.1.5 College and University Classroom Environment Inventory (CUCEI)

In contrast to the questionnaire described in Sections 2.4.1.1 to 2.4.1.4, the CUCEI was established to gather information in higher-education classrooms. It was not designed to assess lecture or laboratory settings, but rather to assess perceptions in small class settings (Fraser & Treagust, 1986). The original version of the CUCEI used common features from the LEI, CES, and ICEQ. The final version of the CUCEI has seven scales, each containing seven items. Each item has the four possible responses of Strongly Agree, Agree, Disagree, and Strongly Disagree (Fraser, 1998a). A typical question in the Task Orientation scale is “Activities in this class are clearly and carefully planned.”

Logan, Crump and Rennie (2006) confirmed that modified versions of CUCEI were valid in two independent studies in New Zealand. The CUCEI was utilized in computing classrooms in secondary schools and tertiary institutions in Wellington. The sample for the tertiary study was 125 students who completed both actual and preferred version of the CUCEI. Whereas the tertiary study involved first-year college students’ perception of their learning environment, the secondary study involved students registered in an (elective) computer course for Grades 12 and 13 at seven Wellington secondary schools. The modified version of CUCEI was found to be valid and reliable in both studies.

2.4.1.6 Questionnaire on Teacher Interaction (QTI)

The QTI was developed in the Netherlands and focuses on the nature and quality of interpersonal relationships between teachers and students (Wubbels, 1993; Wubbels & Brekelmans, in press; Wubbels & Levy, 1993). It assesses students' perceptions of eight behavioral aspects exhibited by teachers: Leadership, Helping/Friendly, Understanding, Student Responsibility and Freedom, Uncertain, Dissatisfied, Admonishing, and Strict. The QTI's items have a five-point frequency response scale ranging from Never to Always. A typical item in the Student Responsibility and Freedom Behavior scale is "She/he gives us a lot of free time". An elementary-school version of the QTI with 48 items was developed and validated by Goh and Fraser (1998) and used in Singapore. Fisher and Cresswell (1998) developed the Principal Interaction Questionnaire (PIQ), based on the QTI, to measure teachers' perceptions of the principal on the same eight dimensions of the interaction between the principal and his/her teachers.

Fisher, Rickards and Fraser (1997) clarify how teachers can use feedback based on the QTI to enhance the classroom environment. Having received feedback based on students' perceptions of teacher interpersonal behaviors in graphical form, one teacher decided to enhance her classroom setting by concentrating on the students' need for clear verbal communication.

Scott and Fisher (2004) used an elementary version of the QTI that had been translated it into standard Malay. This investigation is unique in that an elementary version of the (QTI) in the Standard Malay language was validated with a sample of 3,104 elementary students who were representative of the population of Brunei elementary students.

Lee, Fraser and Fisher (2003) administered another version of the QTI questionnaire in Korean senior high schools. The QTI was translated into Korean and administered to 439 students (99 science-independent stream students, 195 science-oriented stream students and 145 humanities stream students). This study involved assessing three different aspects of the high school science classroom environments in Korea, namely, the degree of implementation of constructivism, the pattern of teacher-student interactions, and the learning environment in laboratory classes. Overall, the study provided support for the validity of the Korean version of the QTI and revealed some interesting differences between the learning environments of different streams.

The QTI has been cross-validated and found to be useful in research applications in various countries. For example, it has been used in the USA (Wubbels & Levy, 1993), Australia (Fisher, Henderson & Fraser, 1995; Henderson, Fisher & Fraser, 2000), Korea (Lee, Fraser & Fisher 2003), Singapore (Goh, & Fraser, 1998; Quek, Wong & Fraser, 2005a, 2005b), and Brunei (Riah, Fraser & Rickards, 1997; Scott & Fisher, 2004).

Fraser, Aldridge and Soerjaningsih (2010) investigated relationships between students' outcomes (achievement and attitudes) and the quality of teacher-student interactions at the university level in Indonesia. The QTI was modified, translated and used with a sample size of 422 students in 12 classes in a private university. The validity of the QTI was supported and differences were found between a computer science and management department in terms of instructor-student interactions. As well, the study identified which types of instructor-student interactions are most likely to promote student outcomes at the university level.

2.4.1.7 Science Laboratory Environment Inventory (SLEI)

Because laboratory settings are essential in science learning, the SLEI was developed specifically for gauging the learning environment of science laboratory classes at the senior-high school and university levels (Fraser, Giddings, & McRobbie, 1995). The SLEI has five scales with seven items in each. Each item has the five possible frequency responses of Almost Never, Seldom, Sometimes, Often, and Very Often to choose from. Typical items are "I use the theory from regular science class sessions during laboratory activities" and "We know the results that we are supposed to get before we commence a laboratory activity". The SLEI includes some negatively-worded items.

The original validation of the SLEI was unusually comprehensive in that it involved 5447 university and senior high-school students in 269 classes in six different countries. (USA, Canada, England, Israel, Australia and Nigeria) (Fraser, Giddings & McRobbie, 1995). Subsequently, in Australia, the SLEI was cross-validated with 1594 science students in 92 senior secondary classes (Fraser & McRobbie, 1995) and with 489 senior secondary biology students (Fisher, Henderson & Fraser, 1997).

In Singapore, a variant of the SLEI called the Chemistry Laboratory Environment Inventory (CLEI) was used specifically in two studies in senior secondary chemistry classes. First, in a study involving 1592 Grade 10 chemistry students in 56 classes in 28 schools, Wong and Fraser (1996) validated the CLEI and established associations between students' attitudes and their perceptions of their laboratory classroom environments. Second, in research involving 497 Grade 10 chemistry students in 18 classes, Quek, Wong and Fraesr (2005a) cross-validated the CLEI and reported sex and stream differences in learning environment perceptions.

Fraser and Lee (2009) assessed science laboratory classroom environments in Korean senior high schools among 439 students (99 science-independent stream students, 195 science-oriented stream students and 145 humanities stream students). When the SLEI was translated into Korean and administered in laboratory classrooms, sound factorial validity and internal consistency reliability were established for the SLEI in addition to its ability to differentiate among the perceptions of students in different classrooms. As well, use of the SLEI revealed differences in the learning environments of different streams.

In a study in Florida, Lightburn and Fraser (2007) evaluated the use of anthropometric activities among 761 high-school science students utilizing the SLEI together with the student outcomes of achievement and attitudes The SLEI's factorial validity, internal consistency reliability and ability to differentiate between classrooms were supported by the data. Results of this study provided some evidence to support the positive influence of using anthropometric activities in terms of students' attitudes and the classroom learning environment.

2.4.1.8 Constructivist Learning Environment Survey (CLES)

The CLES focuses on student-centered settings and was developed to assist researchers and teachers to assess the degree to which a particular classroom's environment is consistent with a constructivist epistemology (Taylor & Fraser, 1991). Additionally, the CLES assists teachers to alter their classroom learning environments in line with critical constructivist epistemology (Taylor, Dawson, & Fraser, 1995). The CLES is available in actual and preferred forms (Kim, Fisher, & Fraser, 1999) and has 30 items (five scales with six items in each scale). Each item has a five-point response scale (Almost Never, Seldom, Sometimes, Often and Almost Always). A typical item in the Personal Relevance scale is "I learn how science can be part of my out-of-school life". The CLES has only one negatively-worded item and its items are arranged in blocks (rather than cyclically or randomly as in other questionnaires). As discussed below, the CLES has been cross-validated in the USA (Nix, Fraser & Ledbetter, 2005), Korea (Kim, Fisher & Fraser, 1999), South Africa (Aldridge, Fraser & Sebela, 2004) and Australia and Taiwan (Aldridge, Fraser, Taylor & Chen, 2000).

Nix, Fraser, and Ledbetter (2005) evaluated an integrated science learning environment by using the CLES among 1079 students in 59 classes in north Texas. A new comparative student version of the CLES was developed to evaluate the impact of an innovative teacher development program (based on the Integrated Science Learning Environment, ISLE, model) in school settings. Answers were recorded in two separate response blocks (science taught by a teacher who attended the ISLE program and science and non-science classes taught by other teachers in the same school) in side-by-side columns with 30 items comprising five scales. The results of the factor analysis with varimax rotation and Kaiser normalization validated the a priori structure of the CLES. More positive perceptions were noted when the classroom environment perceptions of students whose science teachers had attended the ISLE program were compared with students whose teachers had not attended the ISLE program.

Aldridge, Fraser and Sebela's (2004) study involved assisting South African teachers to become reflective practitioners in their daily mathematics classroom teaching using a combination of quantitative and qualitative research methods. The CLES was used to collect quantitative data for the first phase of the study and to provide a profile of learning environment scores for a sample of 1864 students in 43 classes who responded to the CLES. Based on this sample, the CLES was cross-validated for use in South Africa. During the second phase of the study, two teachers used the profiles to assist them in developing strategies for improving the constructivist orientation of their classroom learning environments. Daily journals were kept to help teachers to reflect on their teaching practices. The CLES was administered a second time to determine if the students' perceptions of the constructivist emphasis in their classroom learning environments had changed.

Aldridge, Fraser, Taylor and Chen (2000) investigated constructivist learning environments in a cross-national study in Taiwan and Australia. An aim of the study was to validate and use English and Chinese versions of the CLES in a cross-national study of high-school science classrooms. When the CLES was administered to 1081 students from 50 classes in Australia and 1,879 students from 50 classes in Taiwan, the results confirmed the validity and reliability of the CLES and revealed differences in the classroom environments in the two countries.

Johnson and McClure (2004) used a version of the CLES to provide insights into the classroom learning environments of beginning science teachers. The CLES was administered to 290 upper-elementary, middle-school, and high-school science teachers and preservice teachers and other data were gathered through interviews and classroom observations. This study was part of a larger study of learning environments and teaching practices of beginning science teachers in the USA. Exploratory factor analysis and internal consistency reliability analysis, as well as examination of each item and participants' questions and comments about them, led to a shorter, revised version of the CLES. When the revised version of the CLES was administered during the second, third and fourth years of the study, it exhibited sound validity and reliability.

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

2.4.2 What Is Happening In this Class? (WIHIC)

In Section 2.4.1, I briefly reviewed eight questionnaires which have facilitated the study of classroom learning environments in many parts of the world. However, I did not discuss in Section 2.4.1 the What Is Happening In this Class? (WIHIC), which is another widely-used and extensively-validated classroom learning environment instrument, because it was selected for use in my study. Section 2.4.2.1 provides information about the development and characteristics of the WIHIC. In Section 2.4.2.2, validation studies involving use of the WIHIC in the Western context are discussed whereas, in Section 2.4.2.3, I review studies involving validation of the original, translated, and/or modified versions of the WIHIC in the Asian context.

2.4.2.1 Development and Characteristics of WIHIC

The WIHIC questionnaire, originally developed by Fraser, Fisher, and McRobbie (1996), brings parsimony to the field of learning environments by combining modified versions of the most salient scales from existing instruments with additional scales that address contemporary concerns. In addition, the WIHIC has a class form and an individual form. Therefore, the instrument can be used to assess a student's perceptions of the class as a whole or of his or her own role in a classroom (Fraser, 1999). The original 90-item version of the WIHIC (10 statements in each of 9 scales) was modified to 54 items in seven scales after conducting statistical analyses of data collected from 355 junior high school science students and extensive interviewing of students and teachers. The WIHIC was later expanded to 80 items and field-tested with 1,879 students in 50 classes in Australia and students in 50 classes in Taiwan (Fraser, 1998b; Aldridge, Fraser, & Huang 1999). Based on the results of the field-testing, the WIHIC was modified to a 56-item version (8 items in each of 7 scales). In order to respond to the items in each of the seven WIHIC scales, the respondent indicates how often a practice occurs using the five-point frequency scale of Almost Never, Seldom, Sometimes, Often, and Almost Always.

As discussed in detail in Section 3.4.1, the names of the seven scales in the original version of the WIHIC are Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation and Equity. In my study, I used 25 questions from the 56-question version of the WIHIC to measure students' perceptions of their classroom learning environment. The main reason why I chose the WIHIC for my study is because it has proved to be a valid and reliable tool in many studies in numerous countries around the world. In Section 2.4.2.2, I describe the validation of the WIHIC in Western countries whereas, in Section 2.4.2.3, I provide more information about the validation of the WIHIC in Asian countries. Finally, in Section 2.4.2.4, I briefly review literature concerning several new learning environment questionnaires that are based on the WIHIC.

2.4.2.2 Validation of WIHIC in Western Context

The WIHIC questionnaire has been extensively validated with students at various grade levels and in different subject areas within the Western context. For instance, Raaflaub and Fraser (2003) validated a modified version of the WIHIC with 1,173 high-school mathematics and science students in Canada. After conducting principal components factor analysis with varimax rotation, the a priori eight-factor structure of the modified version of the WIHIC was replicated with nearly all items having a factor loading of at least 0.40 on their a priori scale and no other scale. The internal consistency for each scale was established by Raaflaub and using Cronbach's alpha coefficient for two units of analysis. The alpha coefficient ranged from 0.76 to 0.92 (individual student) and from 0.78 to 0.95 (class mean) for different WIHIC scales, demonstrating satisfactory internal consistency. Additionally, the discriminant validity (mean correlation of one scale with the other scales) for different WIHIC scale ranged from 0.10 to 0.38 using the individual student as the unit of analysis and from 0.18 to 0.45 for the class mean. Therefore, each scale of the modified version of the WIHIC could measure a distinct aspect of the classroom learning environment, although there was some overlap. Furthermore, the eta^2 statistic (the strength of association between class membership and the dependent variable) ranged from 0.01 to 0.11 for different WIHIC scales, indicating that most scales were capable of differentiating significantly between the perceptions of students in the different classes.

In North Carolina, the modified version of the WIHIC was validated with 364 biology students in Grades 9 and 10 (Moss & Fraser, 2001). Another study conducted by MacDowell-Goggin (2005) validated a modified version of the WIHIC with 860 students in Miami-Dade County, Florida. The alpha reliability estimates for the different WIHIC scales ranged from 0.81 to 0.91 for the individual student as the unit of analysis and from 0.85 to 0.94 for the class mean as the unit of analysis, suggesting that all scales of the modified version of the WIHIC possess satisfactory internal consistency. Additionally, the eta^2 statistic (the strength of association between class membership and the dependent variable) ranged from 0.04 to 0.07 for different WIHIC scales, and each scale was capable of differentiating significantly between classes.

Soto-Rodriguez and Fraser (2004) also validated modified English and Spanish versions of the WIHIC in Miami-Dade County, Florida. The sample of 927 science students from Grade 8–10 schools consisted of Limited English Proficient (LEP) and non-LEP students. The results of principal components factor analysis showed that the factor loadings for the modified English version of the WIHIC ranged from 0.58 to 0.90 and for the modified Spanish version they ranged from 0.59 to 0.88. Thus, the a priori six-factor structure of the modified English and Spanish versions of the WIHIC was replicated, with all items loading above 0.40 on their own scale and no other scale.

Another study involving the WIHIC was conducted in Miami-Dade County, Florida by Allen and Fraser (2007). This study validated the WIHIC with 520 Grade 4 and 5 students. The factorial validity of the WIHIC questionnaire was investigated using principal components factor analysis with varimax rotation. Thirty-seven (37) of the original 39 items had a factor loading of at least 0.30 on their a priori scale and no other scale, demonstrating that the WIHIC had satisfactory factorial validity. The alpha reliability coefficient ranged from 0.73 to 0.90 for each scale of the WIHIC, suggesting high reliability estimates. Each WIHIC scale was capable of differentiating significantly between classes. In another study involving younger students in Florida, 172 kindergarten science students and 78 parents responded to a simplified version of the WIHIC that was available in two languages (Spanish and

English). This study supported the factorial validity and reliability of the WIHIC when used with very young students and their parents (Robinson & Fraser, in press).

Castillo, Peiro and Fraser (2005), also in Miami-Dade County, Florida, validated a refined version of the WIHIC. The data collected from the sample of 600 students in 30 classes were subjected to principal components factor analysis with varimax rotation. Each of the 45 items in the refined version of the WIHIC had a factor loading of at least 0.40 on its a priori scale and less than 0.40 on each of the other WIHIC scales. These results provide good support for the factorial validity of the 45-item seven-scale version of the WIHIC used in this study. When the internal consistency reliability of each scale of the refined version of the WIHIC was assessed using Cronbach's alpha coefficient, the reliability for different scales ranged from 0.83 to 0.93 for the student as the unit of analysis and from 0.88 to 0.93 with the class mean as the unit of analysis.

A modified version of the WIHIC was used in evaluating a two-year mentoring program. This study was unique as it drew on the field of learning environments in evaluating this program in terms of teachers' classroom teaching behavior as assessed by their school students' perceptions of their classroom, as well as their attitudes to and achievement in science. The sample consisted of seven Grade 3−5 teachers in southeastern USA and their 573 elementary school students (Pickett & Fraser, 2009). Data analyses supported the WIHIC's factorial validity and reliability. The use of MANOVA and effect sizes supported the efficacy of the mentoring program in terms of some improvements over time in the classroom learning environment and students' attitudes and achievement.

Martin-Dunlop and Fraser (2007) confirmed the validity of the WIHIC in an investigation into the effectiveness of an innovative science course for improving potential elementary teachers' perceptions of laboratory learning environments and attitudes towards science. The sample consisted of 27 classes with 525 female students in a large urban university in California. An open-ended approach was utilized in an attempt to change students' ideas about science laboratory teaching and learning, and to create more positive attitudes towards science. The study revealed large and statistically significant improvements on all scales assessing the laboratory learning environment and attitudes towards science. The biggest improvements were noted for the Open-Endedness and Material Environment scales (with effect sizes of 6.74 and 3.82 standard deviations, respectively). The study also revealed statistically significant attitude-environment associations in both the univariate and multivariate analyses.

Ogbuehi and Fraser (2007) examined the effectiveness of using innovative teaching strategies for enhancing the classroom environment, student attitudes and student conceptual development among middle-school mathematics students in California. The WIHIC questionnaire was utilized with a sample of 661 students from 22 classrooms in four inner-city schools. The effectiveness of the instructional strategy was assessed in terms of classroom environment and attitudes to mathematics for the entire sample, in addition to mathematics achievement for a subgroup of 101 students. The innovative teaching strategies were successful for enhancing classroom environment, attitudes and conceptual development. Associations between students' perceptions of the classroom learning environment and attitudes to mathematics and conceptual development were noted. The WIHIC was found to be valid and a comparison of an experimental group (which experienced the innovative strategy) with a control group supported the efficacy of the innovative teaching methods in terms of learning environment, attitudes and mathematics concepts development. In addition, associations were found between perceptions of classroom learning environment and students' attitudes to mathematics and their conceptual development.

In addition, the WIHIC questionnaire was cross-validated using a sample of 3980 high-school mathematics students from Australia, the UK and Canada (Dorman, 2003). Confirmatory factor analysis supported the seven-scale a priori structure of the instrument, and all items loaded strongly on their a priori scale. All scales had good internal consistency using Cronbach's alpha coefficient, with values ranging from 0.76 to 0.85. The eta^2 statistic (the strength of association between class membership and the dependent variable) ranged from 0.06 to 0.12, which showed that each WIHIC scale differentiated significantly ($p<0.01$) between the different classes in both countries.

In a second study, Dorman (2008) used both the actual and preferred forms of the WIHIC with a sample of 978 secondary school students from Australia. Separate confirmatory factor analyses for the actual and preferred forms supported the seven-scale a priori structure, with fit statistics again indicating a good fit of the models to the data. The use of multitrait-multimethod modeling with the seven scales as traits and the two forms of the instrument as methods supported the WIHIC's construct validity and provided strong evidence of the sound psychometric properties of the WIHIC.

Zandvliet and Fraser (2004, 2005) used the WIHIC with 1040 students in 81 senior high school classes in Australia and Canada. Factor analysis strongly supported the a priori five-scale structure of the WIHIC. Scale alpha reliability coefficients ranged from 0.86 to 0.95, suggesting very good internal consistency. The discriminant validity (mean correlation of one scale with the other scales) ranged from 0.16 to 0.52, demonstrating that these scales measure distinct, though somewhat overlapping, aspects of the psychosocial environment.

Helding and Fraser (in press) translated the WIHIC into Spanish and cross-validated both English and Spanish versions with a sample of 924 students in 38 Grade 9 and 10 science classes in Florida. As well as reporting associations between the learning environment and student outcomes (attitudes and achievement), these researchers found that students of National Board Certified (NBC) teachers had more favourable classroom environment perceptions than students of non-NBC teachers.

Wolf and Fraser (2008) compared inquiry and non-inquiry laboratory teaching in terms of student perceptions of classroom learning environment, achievement, and attitudes toward the science class. Students' perceptions of the learning environment were assessed using the WIHIC among a sample of 1, 434 middle-school science students in 71 classes. This study supported the WIHIC's factorial validity and internal consistency reliability, as well as the effectiveness of the inquiry approach.

2.4.2.3 Validation of WIHIC in Asian Context

Although the WIHIC is a relatively recent instrument for assessing classroom environments, it has been used in the Asian context in English and in numerous Asian languages. These translated and/or modified versions of the WIHIC have been validated in studies conducted in countries such as Korea, Indonesia, Brunei and Singapore.

For example, in Korea, Kim, Fisher, and Fraser (2000) translated the WIHIC into Korean and back-translated it into English to ensure that the English and Korean versions were equivalent. The sample consisted of 543 Grade 8 science students in 12 secondary schools who responded to the Korean version of the WIHIC. Factor analysis resulted in the acceptance of the a priori seven-factor structure of the Korean version of the WIHIC, with nearly all items loading on their a priori scale and no other scale. When the alpha reliability coefficient was used as the index of scale internal consistency, values ranged from 0.82 to 0.92 for different scales of the WIHIC, suggesting that all scales possess satisfactory internal consistency. Additionally, the discriminant validity (mean correlation of one scale with the other scales) ranged from 0.32 to 0.49, suggesting that each WIHIC scale measures a distinct aspect of the classroom environment. The eta^2 statistic (the strength of association between class membership and the dependent variable) ranged from 0.06 to 0.20 for different WIHIC scales, and each scale was capable of differentiating significantly between classes.

In a large-scale study conducted by Margianti, Aldridge, and Fraser (2004) involving 2,498 university students in 50 computing classes in Indonesia, a modified Indonesian version of the WIHIC was validated. Factor analysis showed that nearly all items in the Indonesian-language version of the WIHIC had factor loadings of at least 0.40 on their a priori scale and no other scale. The alpha reliability coefficient ranged from 0.65 to 0.87 for different scales of the modified Indonesian version of the WIHIC, suggesting that all scales possess satisfactory internal consistency. Each scale of the Indonesian version of the WIHIC was found capable of differentiating significantly between classes.

A large-scale study conducted by Khine and Fisher (2001) in Brunei involved a large sample of 1,188 students from 54 science classes in 10 government secondary schools. Both the individual and the class mean were used as the units of analysis when determining the internal consistency reliability. When the Cronbach alpha coefficient was used as the index of scale internal consistency, values ranged from 0.78 to 0.87 for different WIHIC scales using the individual student as the unit of analysis. When using the class mean as the unit of analysis, the alpha coefficient ranged from 0.81 to 0.94 for different WIHIC scales. Each scale was found to be capable of differentiating significantly between the perceptions of students in the different classes.

Chionh and Fraser (2009) investigated the validity and reliability of a modified English version of the WIHIC in Singapore among 2,310 students in 75 10^{th} grade geography and mathematics classes in 38 schools. Principal components factor analysis followed by varimax rotation resulted in the acceptance of the a priori seven-factor structure of the modified English version of the WIHIC with nearly all items loading on their a priori scale and no other scale. The alpha reliability coefficient for the individual student as the unit of analysis for geography ranged from 0.88 to 0.92 and for mathematics from 0.87 to 0.93. Each scale was found to be capable of differentiating significantly between the perceptions of the students in the different classes.

In another study in Singapore, Khoo and Fraser (2008) used a modified version of the WIHIC in the evaluation of adult computer application courses among 250 working adults. Data analysis confirmed a five-factor structure (Trainer Support, Involvement, Autonomy/Independence, Task Orientation, and Equity) for a learning environment questionnaire, and scale alpha reliabilities ranged from 0.77 to 0.92 with the class mean as the unit of analysis. Student satisfaction varied among the sexes and between students of different ages. The SLEI was found to be valid and reliable.

Koul and Fisher (2005) investigated the associations between students' cultural background and their perceptions of their teacher's interpersonal behavior and classroom learning environment in Jammu, India. The study involved 1021 students from 31 classes in seven co-educational private school completing a survey that included the Questionnaire on Teacher Interaction (QTI), the WIHIC and a question relating to cultural background. Data analyses revealed that the WIHIC was valid and reliable. Also, a Kashmiri group of students perceived their classroom environments and teacher interactions more positively than did students from other cultural groups in the study.

Two studies have involved the validation and use of Arabic translations of the WIHIC among tertiary students in the United Arab Emirates. For a sample of 352 college students in 33 classes in Abu Dhabi, Afari, Aldridge, Fraser & Khine (in press) reported attitude-environment associations and that the use of mathematical games promoted a positive classroom environment. In Dubai, when MacLeod and Fraser (2010) administered the WIHIC to 763 college students in 82 classes, it was found that students preferred a more positive actual classroom environment.

Aldridge and Fraser (2000) investigated classroom environments in Australia and Taiwan using English and Mandarin versions of the WIHIC. The Mandarin version underwent a back-translation process to achieve linguistic equivalence with the English version. The English and Mandarin versions of the WIHIC were administered to a sample of 1,081 junior high students in 50 classes in Australia and 1,879 junior high students in 50 classes in Taiwan. Principal components factor analysis followed by varimax rotation resulted in the acceptance of the a priori seven-factor structure of the WIHIC in both countries with nearly all items having a factor loading of at least 0.40 on their a priori scale and no other scale. To establish that each scale had satisfactory internal consistency, Cronbach's alpha coefficient was calculated. Reliability coefficients ranged from 0.81 to 0.91 for the Australian sample and from 0.85 to 0.90 for the Taiwanese sample while using the individual student as unit of analysis. Using the class mean as the unit of analysis, scale reliability estimates ranged from 0.87 to 0.97 in Australia and from 0.90 to 0.96 in Taiwan. The relatively high alpha reliability for each scale of the English and Mandarin versions of the WIHIC suggests that the items in each scale assess a common concept. The eta^2 statistic (the strength of association between class membership and the dependent variable) ranged from 0.07 to 0.15 in Australia and from 0.07 to 0.36 in Taiwan. Each of the seven scales differentiated significantly between the perceptions of the students in the different classes in both countries.

Fraser, Aldridge and Adolphe (2010) reported a cross-national study of classroom environments in Australia and Indonesia. The sample consisted of 1,161 students (594 students from 18 classes in Indonesia and 567 students from 18 classes in Australia). A modified version of the WIHIC questionnaire was administered concurrently to Australia and Indonesia students. The revised version of the WIHIC was validated by principal components factor analysis with varimax rotation. A two-way MANOVA revealed differences between countries and between sexes in students' perceptions of their classroom environments. Also there was a positive association in both countries between the classroom environment and student attitudes to science.

In conclusion, the WIHIC is a learning environments questionnaire that has been used successfully in the Asian context. Numerous studies conducted in Asian countries suggest that the WIHIC can be modified and translated into several Asian languages and still remain a valid and reliable instrument for gathering students' perceptions of their classroom learning environments. These studies provide further support for the validity and usefulness of the WIHIC, which was chosen for use in my study.

2.4.2.4 Questionnaires Based on WIHIC: OBLEQ, TROFLEI and COLES

Numerous researchers have incorporated WIHIC scales into specific-purpose questionnaires tailored to the particular contexts and purposes of their studies. For example, working with a sample of 2638 Grade 8 science students from 50 classes in 50 schools in the Limpopo Province of South Africa, Aldridge, Laugksch, Seopa and Fraser (2006) developed and validated a classroom environment instrument in the Sepedi language for monitoring the implementation of outcomes-based classroom environments. The Outcomes-Based Learning Environment Questionnaire (OBLEQ) contains four scales from the WIHIC, one scale each from the ICEQ and CLES, and a new scale (called Responsibility for Own Learning). As well as validating a widely-applicable questionnaire suited for outcomes-based education, the researchers used case studies to support and check the accuracy of profiles of OBLEQ scores for specific classes.

In order to monitor outcomes-focused education, the Technology-Rich Outcomes-Focused Learning Environment Instrument (TROFLEI) was developed (Aldridge & Fraser, 2008). The TROFLEI incorporates all of the WIHIC's seven scales (Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Investigation. Cooperation and Equity), and also includes three other important scales. The Differentiation scale from the ICEQ assesses the extent to which teachers cater for students differently according to their abilities, rates of learning and interests. Computer Usage assesses the extent to which students use computers as a tool to communicate with other students and to access information. Young Adult Ethos assesses the extent to which teachers give students responsibility and treat them as young adults.

Using a large sample of 2317 students from 166 Grade 11 and 12 classes from Western Australia and Tasmania, Aldridge and Fraser (2008, 2011) reported strong factorial validity and internal consistency reliability for both the actual and preferred forms of the TROFLEI. Aldridge, Dorman and Fraser (2004) used multitrait-multimethod modeling with a subsample of 1249 students. When the 10 TROFLEI scales were used as traits and the actual and preferred forms of the instrument as methods, the results supported the TROFLEI's construct validity and sound psychometric properties, as well as indicating that the actual and preferred forms share a common structure. When the TROFLEI was used in monitoring and evaluating the success of a new school in promoting outcomes-focused education, changes in students' perceptions of their classroom environments over four years supported the efficacy of the school's educational programs (Aldridge & Fraser 2008, 2011). Using structural equation modeling with a sample of 4146 Grade 8–13 students, Dorman and Fraser (2009) used the TROFLEI to establish associations between students' affective outcomes and their classroom environment perceptions.

The Constructivist-Orientated Learning Environment Survey (COLES) incorporates numerous scales from the WIHIC into an instrument that is designed to provide feedback as a basis for reflection in teacher action research. In constructing the COLES, Aldridge, Fraser, Bell and Dorman (in press) were especially conscious of the omission in all existing classroom environment questionnaire of important aspects related to the assessment of student learning. The COLES incorporates six of the WIHIC's seven scales (namely, Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Cooperation and Equity), while omitting the WIHIC's Investigation scale. Like the TROFLEI, the COLES also includes the scales of Differentiation and Young Adult Ethos. In addition, the COLES includes the Personal Relevance scale from the CLES (the extent to which learning activities are relevant to students' everyday out-of-school experiences). The two new COLES scales related to assessment are called Formative Assessment (the extent to which students feel that the assessment tasks given to them make a positive contribution to their learning) and Assessment Criteria (the extent to which assessment criteria are explicit so that the basis for judgements is clear and public).

For a sample of 2043 Grade 11 and 12 students from 147 classes in 9 schools in Western Australia, data analysis supported the sound factorial validity and internal consistency reliability of both actual and preferred versions of the COLES. During action research with teachers, use was made of feedback based on students' responses to both the actual and preferred versions of the COLES, in conjunction with reflective journals, written feedback, discussion at a forum, and teacher interviews. Aldridge et al. (in press) reported the experiences of these teachers concerning the viability of using feedback from the COLES as part of their action research aimed at improving their classroom environments.

2.5 Student Attitudes toward Mathematics

My evaluation of the exchange-of-knowledge method involved not only the classroom learning environment, but also student attitudes toward mathematics.

Because classroom environment has been found to be a strong predictor of both achievement and attitudes even when a comprehensive set of other factors was held constant, my study included an investigation of attitude-environment associations. This section briefly reviews literature related to students' attitudes in terms of the definition and assessment of attitudes.

The definition of the terms linked with students' affective outcomes has caused confusion in the past. According to Peterson and Carlson (1979), terms such as interest or attitudes have been used loosely and without elucidation. Krathwohl, Bloom, and Masia (1964) developed a taxonomy in which affective behaviors are placed along a hierarchical continuum. This helped to clear up misunderstandings about the terms used to describe affective behaviors. Klopfer (1976) took this taxonomy one step further and developed a classification system for the affective domain specifically related to science education. The structure involves three categories: events in the natural world (awareness and an emotive response to experiences that require no formal study; activities (students' participation in activities related to science as a means of knowing about the world); and inquiry (scientific inquiry processes). The attitude scales used in the present study focus on Klopfer's second category, which relates to students' attitudes toward their science activities.

Students' attitudes toward a subject have been measured using a range of techniques, including interviews, open-ended questions, projective techniques, closed-item questionnaires and preference rankings (Laforgia, 1988). In the past, instruments have been designed to elicit the attitudes of students toward science (Martin-Dunlop

& Fraser, 2007; Fisher, 1973; Fraser, 1978, 1981; Mackay, 1971; Wubbels, Creton, & Hoomayers, 1985). Many such instruments have been criticized on conceptual and empirical grounds (Gardner, 1975; Munby, 1980; Schibeci, 1984) and because of their inability to be used in different countries (Schibeci, 1986).

There are numerous scales for assessing science-related attitudes. The Test of Science Related Attitudes (TOSRA) is of particular interest and was used by Fraser (1978, 1981) to measure students' attitudes toward their science classes. Fraser based the scales of his instrument on Klopfer's (1976) taxonomy of the affective domain related to science education. A modified version of the TOSRA has been used in previous studies in non-Western countries with a high degree of reliability and validity (Goh, 1994; Goh & Fraser, 1998; Wong & Fraser, 1996). The TOSRA uses the Likert scaling technique (Likert, 1932), in which the respondent's position on a scale ranges from positive to negative on a five-point range (e.g. strongly agree, agree, uncertain, disagree and strongly disagree).

Martin-Dunlop and Fraser (2007) used the TOSRA in evaluating the effectiveness of an innovative science course for improving prospective elementary teachers' perceptions of laboratory learning environment and attitudes towards science. The sample consisted of 27 classes with 525 female students in a large urban university. The data reported large and statistically significant improvements on all seven scales assessing the laboratory learning environment and attitudes towards science. The TOSRA was validated for this sample.

The Test of Science Related Attitudes (TOSRA) was modified for mathematics to form the Test of Mathematics Related Attitudes (TOMRA), which was used for this study for the purpose of exploring associations between students' attitudes to mathematics and their perceptions of the learning environment. The TOMRA also has been used in several past studies (e.g. Mink & Fraser, 2005; Spinner & Fraser, 2005) in mathematics education. Ogbuehi and Fraser (2007) validated the TOMRA in a study that investigated learning environment, attitudes and conceptual development associated with innovative strategies in middle-school mathematics in California. The TOMRA was used to explore students' perceptions of the classroom learning environment and attitudes toward mathematics.

Hardy Deveaux and Fraser (2005) also validated the TOMRA and used it in an investigation of classroom environment and student outcomes among elementary mathematics students using portfolios. The TOMRA was utilized to evaluate the success of the use of portfolios in terms of students' attitudes to mathematics. Data analysis supported the factorial validity and reliability of the TOMRA.

TOMRA's seven scales are Social Implication of Mathematics, Normality of Mathematicians, Attitude to Mathematical Inquiry, Adoption of Mathematical Attitudes, Enjoyment of Mathematics Lessons, and Leisure Interest in Mathematics and Career Interest in Mathematics. The seven scales are suitable for group administration and all can be administered within the duration of a normal class lesson. In addition, the TOMRA and TOSRA have been carefully developed and extensively field tested and has been shown to be highly reliable (Fraser, 1981).

A crucial benefit that TOMRA has over some other attitude questionnaires is that it provides a separate score for a number of distinct attitudinal aims instead of a single overall score. This makes it possible to obtain a 'profile' of attitude scores for groups of students (Fraser, 1981).

For this study, it was considered pertinent to modify and make use of the TOMRA to measure students' attitudes toward mathematics classes in elementary and middle schools in Hinesville, Georgia. Several revised TOMRA scales (e.g. Attitude to Mathematical Inquiry and Enjoyment of Mathematics) were selected for inclusion in my study. The TOMRA is discussed further in Section 3.4.2 of the methods chapter.

2.6 Chapter Summary

The purposes of my study included validating the What Is Happening In this Class? (WIHIC) and Test of Mathematics Related Attitudes (TOMRA) and evaluating the relative effectiveness of traditional teaching methods and of the exchange-of-knowledge method in terms of classroom learning environments, students' attitudes toward mathematics and achievement. As well, I investigated associations between students' outcomes (attitudes and achievement) and their perceptions of the classroom learning environment. Therefore, this literature review in Chapter 2 encompassed the following topics: traditional and constructivist mathematics instruction; cooperative learning and the exchange-of-knowledge method; instruments used for assessing classroom learning environments (Learning Environment Inventory, Classroom Environment Scale, Individualized Classroom Environment Questionnaire, My Class Inventory, College and University Classroom

Environment Inventory, Questionnaire of Teacher Interaction, Science Laboratory Environment Inventory, and Constructivist Learning Environment Survey); and the questionnaire chosen for my study – What Is Happening In this Class? (WIHIC) (including its development and characteristics of the WIHIC, validation in a Western context, and validation in an Asian context).

An overview of the field's foundations and the conceptual contributions made in the field of learning environments included the earlier works of Murray (1938) and Lewin (1936) and later those of Walberg (1979) and Moos (1979). There have been numerous studies of classroom environment in various parts of the world over the years (Fraser, 1998a, in press). Although most of past learning environment studies have been performed in Western countries, a growing number of studies have been initiated in non-western countries.

A brief literature review was provided of the traditional mathematics setting and its many reforms. Many students are not prepared in mathematics for competing in a global society. There remains, however, a profound gap between the lack of mathematical knowledge and skills that most students learn in school and the knowledge and skills in mathematics that they will need to be competitive in the twenty-first century. Mathematics should be comprehensible to everyone, not to just a few. There remain many problems in the traditional way of teaching, such as lack of reasoning capabilities, lack of understanding of basic concepts, and the disconnection between mathematics and real-world situations.

The exchange-of-knowledge method (a cooperative learning strategy) was considered as a very promising approach to improving mathematics teaching. In addition to cooperative learning influencing academic achievement, it also positively influences students' attitudes. My study evaluated the exchange-of-knowledge method relative to the traditional teaching method in terms of students' perceptions of their classroom learning environment, attitudes towards mathematics, and achievement in mathematics.

The most common line of classroom learning environment research has involved investigating associations between classroom environment and students' outcomes. My study included an investigation of associations between students' outcomes (attitudes and achievement) and their perceptions of the classroom learning environment.

Because my evaluation of the exchange-of-knowledge method also involved students' attitudes to mathematics as criteria of effectiveness, this chapter also included a review of literature about attitudes and their assessment. In particular, consideration was given to the Test of Science Related Attitudes (TOSRA), which was modified to form the Test of Mathematics Related Attitudes (TOMRA) in my study. An overview was provided of the TOSRA and TOMRA in terms of the dimensions assessed, the response format, the number of items, their validity, and their use in past research.

Chapter 3

RESEARCH METHODS

3.1 Introduction

The present study evaluated whether the exchange-of-knowledge method was more effective than traditional methods of teaching in terms of classroom learning environment, student attitudes toward mathematics and achievement in mathematics. In addition, my research involved the validation of learning environment and attitude questionnaires, and the investigation of associations between the learning environment and student outcomes. This chapter describes and justifies the research methods used in the present study using the following headings:

- Research Aims (Section 3.2)
- Sample of Schools and Students (Section 3.3)
- Instrumentation (Section 3.4)
    - What Is Happening In this Class? (WIHIC) (Section 3.4.1)
    - Test of Mathematics Related Attitudes (TOMRA) (Section 3.4.2)
- Data Collection and Entry (Section 3.5)
- Data Analysis (Section 3.6)
- Conclusion (Section 3.7).

3.2 Research Aims

Quantitative data-collection methods were utilized in the present study based on the use of questionnaire surveys. Students' perceptual measures of classroom environment were employed because it is informative to have students reporting on their education. As well, attitude scales and an achievement measure were included in my research. My research questions are listed below:

Research Question # 1

Are modified versions of widely-applicable instruments for assessing classroom environment and attitudes to mathematics valid when used among elementary and middle-school students in Georgia:

a. What Is Happening In this Class? (WIHIC)
b. Test of Mathematics Related Attitudes (TOMRA)?

Research Question # 2

Is the exchange-of-knowledge method more effective than traditional teaching methods in terms of:

a. classroom learning environment
b. student attitudes toward mathematics
c. student achievement in mathematics

Research Question # 3

Are there associations between students' outcomes (attitudes and achievement) and their perceptions of the classroom learning environment?

3.3 Sample of Schools and Students

The city of Hinesville/Fort Stewart is located in, and covers approximately half the area of, Liberty County, Georgia. It is a transit city because of the Fort Stewart military installation. The study was conducted in two schools in Liberty County, namely, Joseph Martin Elementary and Snelson Golden Middle Schools. Joseph Martin Elementary is located in Hinesville and accommodates students from kindergarten to fifth grade. Snelson Golden Middle School is right next to Joseph Martin Elementary and accommodates Grade 6−8 students. Joseph Martin is the feeder school for Snelson Golden Middle School.

Liberty County’s 2000 Census reports that 11.1% of the households were headed by females and included children below 18 years of age. The total number of households with children below 18 years represented 50.5% of all households in the county. The average household income in Liberty County in 1999 was about $33,477, compared with the state’s median household income of $42,433. In 1999 in Liberty County, 19.2% of the children below 18 years lived beneath the poverty level. Therefore many of the families of students attending Joseph Martin Elementary and Snelson Golden Middle Schools were living below the poverty level.

In order to assist low-income families with students who attend public schools to become academically successful, the federal government created the Title 1 program. Joseph Martin Elementary and Snelson Golden Middle are both Title 1 schools. Title 1 is a government program which provides pecuniary assistance to schools with large percentages of economically-disadvantaged children in order to help them to meet challenging state academic standards. Also, Title 1 funds provide additional educational support and learning opportunities to help low-achieving children to master challenging curricula and to meet state standards for core academic curricula. For instance, monies are allocated for additional instruction in reading and mathematics, as well as to special preschool, after-school, and summer programs aimed at enhancing and reinforcing the regular school core curriculum.

The student population at Joseph Martin Elementary is ethnically made up of 37% White Non-Hispanic, 48% Black Non-Hispanic, 11% Hispanic, and 4% other. The student population at Snelson Golden is ethnically made up of 33% White, 57% Black, 7% Hispanic, and 3% Asian.

The study involved 99 fifth-grade students at Joseph Martin Elementary and 413 Grade 6–8 students from Snelson Golden Middle School, making a total of 512 students, who provided complete data at both pretesting and posttesting.

The exchange-of-knowledge method was utilized in one fifth grade classroom consisting of 30 students which comprised the experimental group for my study. The other classes utilized traditional methods of teaching mathematics in their classrooms. Out of 30 students in the experimental group who started with the present research study, only 22 students provided complete data for the research. This reduction in the size of the experimental group occurred because Hinesville is a transit city, because of students moving in and out of the district as military deployment occurred, and because some spouses returned to their home town with their children while their partners were deployed interstate or overseas.

The smallness of the experimental group (n = 22) relative to the size of the control group (n = 490) is an acknowledged shortcoming of my study. This occurred because of practical difficulties in achieving my intended and larger sample of students of teachers who were willing to teach the exchange-of-knowledge method as part of my study. In turn, the smallness of this sample limited the internal and external validity of my research.

3.4 Instrumentation

Two instruments were utilized to gather data for this study: the What Is Happening In this Class? (WIHIC) questionnaire to measure students' perceptions of their classroom environment; and the Test of Mathematics Related Attitudes (TOMRA) to assess students' attitudes towards their mathematics classes. As well, a measure of mathematics achievement was incorporated into the research.

In the present study involving students' perceptions of the learning environment and students' attitudes toward mathematics, it was necessary to choose suitable assessment instruments. From an extensive list of existing classroom environment instruments reviewed in Chapter 2 – including the Science Laboratory Environment Inventory (SLEI), Constructivist Learning Environment Survey (CLES), College and University Classroom Environment Inventory (CUCEI), Learning Environment Inventory (LEI), Classroom Environment Scale (CES), My Class Inventory (MCI), Questionnaire on Teacher Interaction (QTI), and Individualized Classroom Environment Classroom Environment Questionnaire (ICEQ) – the What Is Happening In this Class? (WIHIC) questionnaire was selected. The Test of

Mathematics Related Attitudes (TOSRA) was selected and modified for assessing students' attitudes to mathematics. Sections 3.4.1 and 3.4.2 below describe the WIHIC and TOMRA, respectively.

3.4.1 What Is Happening In this Class? (WIHIC)

In my study, a modified version of the WIHIC questionnaire was employed to measure students' perceptions of their classroom environment. The WIHIC, initially developed by Fraser, Fisher and McRobbie (1996), combines important scales from a wide array of existing learning environment instruments with scales evaluating dimensions of current educational concern, such as equity. This economical learning environment instrument includes both a class form (which measures a student's perceptions of the class as a whole) and a personal form (which measures a student's perceptions of his/her role in the classroom).

The personal form of the WIHIC questionnaire was used to measure the perceptions of pupils of the actual classroom learning environment. I chose the personal form because Fraser, Giddings and McRobbie (1995) contend that learning environment can be more accurately assessed by asking pupils for their personal perceptions of their roles in the classroom, rather than their perceptions of the learning environment of the class as a whole. Some items from all of the WIHIC's seven scales were chosen initially to measure aspects of the learning environment (although some of these scales subsequently were lost during scale validation). A sample of 99 Grade 5 students and 413 Grade 6–8 students completed the WIHIC and TOMRA questionnaires. Students responded to all items using the same Likert response scale that is used with the TOMRA (Strongly Agree, Agree, Not Sure, Disagree and Strongly Disagree). Using the same response alternatives for both WIHIC and TOMRA items simplified and shortened the response process for students.

Originally, the WIHIC was developed through two versions. The first version with 80 items was administered to 355 students in 17 Grade 9 and 10 mathematics and science classrooms in five Australian schools (Fraser, Fisher & McRobbie, 1996). After a series of statistical analyses, however, only 56 items survived. The original Autonomy/Independence and Understanding scales were entirely excluded. A second version of the instrument was developed with an Autonomy/Independence scale added, comprising the 54 items that survived the previous statistical analyses together with additional items to make an 80-item version of the revised instrument. With the inclusion of Autonomy/Independence in the revised instrument, this version of the WIHIC contained eight scales, namely, Student Cohesiveness, Teacher Support, Involvement, Autonomy/Independence, Investigation, Task Orientation, Cooperation and Equity. When Fraser, Fisher and McRobbie (1996) field tested the first version of the WIHIC, they reported satisfactory factorial validity, internal consistency reliability and discriminant validity, and each scale was capable of differentiating between the perceptions of students in different classrooms.

A validation of the second version of the WIHIC was provided in a cross-national study involving junior high school science students in Taiwan and Australia (Aldridge, Fraser & Huang 1999). In this cross-national study, the 70-item English version of the personal form of the WIHIC (without the Autonomy/Independence scale) was translated into Chinese and then back-translated into English by people who were not involved in the original translation. The Australian researchers checked the back translation and, for some items, modification was necessary either to the English version, the Chinese version or both versions. After modification to some items of the WIHIC, the questionnaire was tried out in several Australian Grade 7–10 science classes. This was followed by student interviews conducted by the researchers. Similar field testing and student interviews were also conducted in Taiwan. The 70-item version was administered to a sample of 1,081 Grade 8 and 9 general science students from 50 classes in 25 schools in Western Australia and 1,879 Grade 7–9 students from 50 classes in 25 schools in Taiwan. This led to a final 56-item 7-scale version of the WIHIC. Table 3.1 provides a scale description and sample item for the final 7-scale version of the WIHIC proposed by Aldridge, Fraser and Huang (1999).

TABLE 3.l Scale Description and Sample Item for Each Scale in Original Version of WIHIC

Scale	Description	Sample Item
Student Cohesiveness	Extent to which students know, help and are friendly toward each other.	I am friendly to members of this class.
Cooperation	Extent to which students collaborate and support each other.	When I work in groups in this class, there is teamwork.
Teacher Support	Extent to which teacher is interested in the students, while displaying characteristics of helpfulness, truthfulness, friendliness, etc.	The teacher's questions help me to understand.
Involvement	Extent to which students' involvement reflects enjoyment.	I discuss ideas in class.
Investigation	Emphasis on the skills and processes of inquiry and their use in problem solving and investigation.	I explain the meaning of statements, diagrams and graphs.
Task Orientation	Extent to which it is important to complete activities planned and to stay on the subject matter.	Getting a certain amount of work done is important to me.
Equity	Extent to which students are treated equally by the teacher.	I get the same opportunity to answer questions as other students do.

Items in the original WIHIC are scored 5,4,3,2 and 1 for the responses Almost Never, Seldom, Sometimes, Often and Very Often. In my study, the response format was changed so that items were scored 5, 4, 3, 2 and 1, respectively, for the responses SA, A, N, D and SD.

Data collected from Australia and Taiwan were analyzed to establish the reliability and validity of the questionnaire (Aldridge & Fraser, 2000). Principal components factor analysis followed by varimax rotation resulted in a seven-factor structure for the WIHIC for both countries, thus supporting the seven *a priori* structure of the questionnaire. Reliability coefficients for different scales, using the class mean as a unit of analysis, ranged from 0.87 to 0.97 for the Australian sample and from 0.90 to 0.96 for the Taiwanese sample. The mean correlation of a scale with other scales using the class mean as the unit of analysis varied from 0.41 to 0.58 for Taiwanese students and from 0.44 to 0.59 for Australian students. Analyses of variance (ANOVA), with class membership as the independent variable and each WIHIC scale as the dependent variable, revealed that the eta^2 statistic (the proportion of variance in an environment scale accounted for by class membership) ranged from 0.07 to 0.15 in Australia and from 0.07 to 0.36 in Taiwan. Most WIHIC scales were able to differentiate significantly between the perceptions of students in different classes in both Australia and Taiwan.

According to Rawnsley and Fisher (1997), the WIHIC was cross-validated with 490 Grade 9 students in 23 mathematics classes in Australia. The validity and reliability of the instrument for studying the classroom environment in mathematics classes were confirmed. Aldridge, Fraser and Ntuli (2009) confirmed the WIHIC's validity and reliability for a sample which included 31 teachers and 1077 students in South Africa. The WIHIC has frequently been used and validated in a number of other countries, including Singapore (Chionh & Fraser, 2009; Khoo & Fraser, 2008), Brunei (Riah & Fraser, 1998), Canada (Zandvliet & Fraser, 2004, 2005), Indonesia (Fraser, Aldridge & Adolphe, 2010), the United Arab Emirates (Afari et al., in press;

MacLeod & Fraser (2010), South Africa (Aldridge, Fraser & Ntuli, 2009), and Korea (Kim, Fisher & Fraser, 2000). Dorman (2003) validated the WIHIC questionnaire in a cross-national study in Australia, Canada and England using a sample of 3,602 students from 29 schools.

The WIHIC has also been validated in several states in the USA. In North Carolina, the modified version of the WIHIC was validated with 364 biology students in Grades 9 and 10 (Moss & Fraser, 2001). In Miami-Dade County, Florida, the WIHIC was validated by MacDowell-Goggin (2005) with 860 students, by Soto-Rodriguez and Fraser (2004) with a sample consisting of 927 science students in Grades 8–10, and by Allen and Fraser (2007) with 520 Grade 4 and 5 students. Allan and Fraser reported that the original 39 items had a factor loading of at least 0.30 on their *a priori* scale and no other scale, demonstrating the WIHIC's satisfactory factorial validity, and that the alpha reliability coefficient ranged from 0.73 to 0.90 for different scales of the WIHIC, suggesting high reliability estimates. Also each WIHIC scale was capable of differentiating significantly between classes. In addition, the WIHIC has been validated in the USA with 573 Grade 3–5 students and their teachers in southeastern USA (Pickett & Fraser, 2007), 1434 middle-school science students in New York (Wolf & Fraser, 2008), 661 middle-school mathematics students in California (Ogbuehi & Fraser, 2007), and 525 university science students in California (Martin-Dunlop & Fraser, 2008).

The versatility and validity of the WIHIC in a variety of situations made it relevant for my research. An examination of salient scales and individual items revealed that, with modification, the WIHIC would be suitable for assessing the learning environment of the elementary-level and middle-school mathematics students in my study. The WIHIC was also chosen for this study because of its sound validity and reliability in past research, and because of its predictive validity for both cognitive and affective student outcomes (e.g. Fraser, 2002, in press).

In my study, the personal form of the WIHIC questionnaire was used to measure students' perceptions of the actual classroom learning environments. I chose the personal form because Fraser, Giddings and McRobbie (1995) contend that learning environment can be more accurately assessed by asking pupils for their personal perceptions of their roles in the classroom, rather than their perceptions of the learning environment of the class as a whole. Although the original 7-scale version of the WIHIC (see Table 3.1) contains 56 items, I reduced the number of WIHIC items to 25 because of the young age of students in my sample. With this reduction in the number of items, it was important to check whether the *a priori* factor structure still applied.

Table 3.2 shows how many items were deleted from each original WIHIC scale to reduce its length from 56 items to the revised 25-item version used in my study. As well as other ways of reducing the length of the WIHIC, I combined the originally-separate 8-item scales of Student Cohesiveness and Cooperation into a single 6-item scale called Student Cohesiveness/Cooperation and combinined the originally-separate 8-item scales of Involvement and Investigation into a single 7-item scale called Involvement/Investigation.

In shortening the original WIHIC for use in my study, an effort was made to choose items with relatively simple wording that would be comprehensible by students in my sample. In addition, a small number of items were shortened and simplified. For example, the original WIHIC item "I help other class members who are having problems with the work" was simplified to "I help other class members who are having trouble".

Table 3.2 also shows the number of items that survived the validation (especially factor analysis) procedures reported later in Chapter 4 (Section 4.2.1). This table shows that a refined version of the WIHIC used to answer my research questions contained a total of 17 items, with the Involvement/Investigation scale lost completely, with one item removed from the Student Cohesiveness/Cooperation scale, and with the refined and revised version being identical for the other three scales (Teacher Support, Task Orientation, and Equity).

Appendix A provides a copy of the revised 25-item of the WIHIC that was administered in my study.

TABLE 3.2 Number of Scales and Items in Original, Revised and Refined Versions of WIHIC

Scale	Number of Items		
	Original[a]	Revised[b]	Refined[c]
Student Cohesiveness/Cooperation	8 + 8	3 + 3	5
Teacher Support	8	4	4
Involvement/Investigation	8 + 8	5 + 2	0
Task Orientation	8	3	3
Equity	8	5	5
Total	56	25	17

[a] Original 7-scale 56-item version of Fraser, Aldridge and Huang (1999)
[b] Revised version administered in my study
[c] Refined version of the revised version used in my study after the factor analysis reported in Chapter 4

3.4.2 Test of Mathematics Related Attitudes (TOMRA)

To assess students' attitudes towards mathematics in my study, the Test of Mathematics Related Attitudes (TOMRA) was used. Fraser (1978) developed the Test of Science Related Attitudes (TOSRA) to measure seven distinct science-related attitudes among secondary school students. TOMRA, based on TOSRA, is designed to gauge seven parallel and distinct mathematics-related attitudes among secondary school students. The design, format and structure of the TOMRA questions are kept the same as the TOSRA, but the word 'science' is changed to 'mathematics'.

The scales of this refined version were found to display satisfactory internal consistency reliability, test-retest reliability and discriminant validity (Fraser, 1981a) in previous research. TOMRA's seven scales are Social Implications of Mathematics, Normality of Mathematicians, Attitude to Mathematical Inquiry, Adoption of Mathematical Attitudes, Enjoyment of Mathematics Lessons, Leisure Interest in Mathematics and Career Interest in Mathematics. The seven scales are suitable for group administration and all can be administered within the duration of a normal class lesson. Furthermore, the TOMRA and TOSRA have been carefully developed and comprehensively field tested and have been shown to be highly reliable (Fraser, 1981a). TOMRA items involve a response format, first described by Likert (1932), which requires students to express their degree of agreement with each statement using a five-point scale consisting of the responses of Strongly Agree, (SA), Agree (A), Not Sure (NS), Disagree (D), and Strongly Disagree (SD) (Fraser, 1981a).

In addition, teachers and researchers have found TOMRA to be useful and convenient for measuring and monitoring progress of the mathematics-related attitudes of individual students or whole classes of students. The present study utilized the TOMRA in a pretest and posttest design in order to find out if students had changed their mathematics-related attitudes over a period of time while the exchange-of-knowledge method was being used.

The scales in the original TOSRA and TOMRA were designed to cover the different types of attitudes described by Klopfer (1971). Table 3.3 presents for each scale its name, its classification according to Klopfer (1971), and a sample item for each TOMRA scale. Literature related to TOSRA was reviewed in more detail in Section 2.6 in Chapter 2.

TABLE 3.3 Scale Classifications and Sample Item for Each Scale in Original Version of TOMRA

Scale	Klopfer (1976) classification	Sample Item
Attitude to Mathematical Inquiry	Acceptance of mathematics inquiry as a way of thought	I would rather find out about things by asking an expert than by doing an experiment. (-)
Enjoyment of Mathematics Lessons	Enjoyment of mathematics learning experiences	I really enjoy going to mathematics lessons. (+)
Social Implications of Mathematics	Manifestation of favorable attitudes towards mathematics and mathematicians	Mathematics helps to make life better. (+)
Leisure Interest in Mathematics	Development of interests in mathematics and mathematics-related activities	I dislike reading books about mathematics during my holidays. (-)
Career Interest in Mathematics	Development of interest in pursuing a career in mathematics	A career in mathematics would be dull and boring. (-)
Adoption of Mathematical Attitudes	Adoption of 'mathematical attitudes'	I find it boring to hear about new ideas. (-)
Normality of Mathematicians	Manifestation of favorable attitudes towards mathematics and mathematicians	Mathematicians like sport as much as other people. (+)

(+) These items are scored 5, 4, 3, 2, and 1, respectively, for the responses SA, A, N, D, and SD.
(-) These items are scored 1, 2, 3, 4, and 5, respectively, for the responses SA, A, N, D and SD.

The primary benefit that TOMRA has over some other mathematics attitude questionnaires is that it yields a single overall score instead of a separate score for a number of distinct attitudinal aims. This makes it possible to obtain a ‘profile’ of attitude scores for groups of students (Fraser, 1981a).

The TOSRA has been found to be reliable and valid in several countries, including Taiwan and Australia (Aldridge, Fraser & Huang 1999) with a sample of 1,081 Grade 8 and 9 general science students from 50 classes in 25 schools in Western Australia and 1,879 Grade 7–9 students from 50 classes in 25 schools in Taiwan, and Indonesia and Australia (Fraser, Aldridge, & Adolphe 2010) in a cross-national study of secondary science classrooms involving 1,161 students (594 students from 18 classes in Indonesia and 567 students from 18 classes in Australia). In the USA, Allen and Fraser (2007) involved a sample of 520 Grade 4–5 science students and 120 parents in providing their attitudes to science and in cross-validating TOSRA.

A small number of research studies in mathematics have been completed using the TOMRA. Mink and Fraser (2005) evaluated a K–5 mathematics program which integrated children’s literature. This one-year study involved 120 fifth-grade students whose teachers participated in a program entitled Project SMILE (Science and Mathematics Integrated with Literary Experiences). The TOMRA exhibited satisfactory reliability and factorial validity. Spinner and Fraser (2005) evaluated an innovative mathematics program in terms of classroom environment, student attitudes, and conceptual development with two groups of fifth graders using the Class Banking System. Analyses supported the TOMRA’s reliability and validity. In California, Ogbuehi and Fraser’s (2007) use of TOMRA with a sample of 661 middle-school mathematics students from 22 classrooms in four inner-city schools supported its factor structure, internal consistency reliability, and discriminant validity.

TABLE 3.4 Number of Scales and Items in Original, Revised and Refined Versions of TOMRA

Scale	Number of Items		
	Original[a]	Revised[b]	Refined[c]
Attitude to Mathematical Inquiry	10	5	5
Enjoyment of Mathematics Lessons	10	8	6
Social Implications of Mathematics	10	5	0
Leisure Interest in Mathematics	10	6	0
Career Interest in Mathematics	10	4	0
Adoption of Mathematical Attitudes	10	0	0
Normality of Mathematicians	10	0	0
Total	70	28	11

[a] Original 7-scale 70-item version of Fraser (1981a)
[b] Revised version administered in my study
[c] Refined version of the revised version used in my study after the factor analysis reported in Chapter 4

Table 3.4 shows how I shortened the original 70-item version of TOMRA to form a shorter and revised version containing only 28 items. First, the two TOMRA scales of Adoption of Mathematical Attitudes and Normality of Mathematicians were omitted altogether from my study because they were considered to be of less salience to my research aims and because of the relative complexity of the language used in their items. For the remaining five scales, Table 3.4 shows that the original 10-item TOMRA scales were reduced in length to 4–8 items each.

Table 3.4 also shows the number of TOMRA items that survived the factor analysis described later in Chapter 4. This table shows that the refined version of TOMRA used in answering my research questions contained only 11 items (out of 28 items), with all 5 items retained in the Attitude to Mathematical Inquiry scale and with 2 items removed to form a 6-item Enjoyment of Mathematics Lessons scale. Factor analysis led to the complete removal of the other three TOMRA scales (Social Implications of Mathematics, Leisure Interest in Mathematics, and Career Interest in Mathematics).

3.4.3 Assessment of Mathematics Achievement

At the beginning and the end of each academic school year, a mathematics achievement test is administered to measure students' academic performance. This achievement test is mandated by Liberty County Schools in Georgia and is written by teachers at the school(s) concerned. Its items are of multiple-choice format. It incorporates all mathematics skills for 5th grade that are covered by the Georgia Criterion-Referenced Competency Test.

In my study, this teacher-developed test was used to assess achievement. This measure was administered as a pretest in September and then later as a posttest in May.

3.5 Data Collection and Entry

When the questionnaires were ready for administration, the researcher contacted the Superintendent of Liberty County Board of Education for permission to administer these two questionnaires in Joseph Martin Elementary and Snelson Golden Middle School. Permission was also obtained from the principals at Joseph Martin and Snelson Golden Schools. A letter was sent to the students' home requesting parents' consent for their children to be involved in my study. When permission was granted, the researcher sent the required number of questionnaires to all mathematics teachers at Joseph Martin Elementary and Snelson Golden Middle with instructions about how to administer the questionnaires. Any student who was involved in the study also gave his/her consent to participate. Learning environment and attitude scales were administered as pretests near the beginning of the school year and again as posttests towards the end of the school year (i.e. the duration of the intervention was a school year).

Once the questionnaires were received, the researcher labeled and grouped the different grades levels by teacher names and student names. Student data were entered into Microsoft Excel Program in alphabetical order by teachers' classes. Each student wrote his/her name, teacher's name, grade, and period on the surveys. This request was aimed at identifying students according to their classes.

3.6 Data Analysis

The Statistical Package for Social Studies (SPSS) Version 18 was utilized to analyze students' responses to the WIHIC and TOMRA to provide evidence regarding factor structure and scale internal consistency reliability. As well, I explored the ability of each WIHIC scale to differentiate between the perceptions of students in different classes. A principal components factor analysis with varimax rotation was used to determine whether all of the 25 items in the revised 5-scale version of the WIHIC shown in Table 3.2 (Student Cohesiveness/Cooperation, Teacher Support, Involvement/Investigation, Task Orientation, and Equity) formed five independent measures of the psychosocial learning environment. As noted in Table 3.2 and reported in detail in Section 4.2.1, out of the five WIHIC scales, only four scales were retained in the refined version in this study: Student Cohesiveness/Cooperation, Teacher Support, Task Orientation, and Equity.

A principal components factor analysis with varimax rotation was also used to determine whether all of the 28 items in the five scales in the revised version of TOMRA shown in Table 3.4 (Attitude to Mathematical Inquiry, Enjoyment of Mathematics Lessons, Social Implications of Mathematics, Leisure Interest in Mathematics, Career Interest in Mathematics) formed five independent measures of students' attitudes to mathematics. Out of the five scales and 28 items of the revised version of TOMRA, only 11 items in two scales survived the factor analysis and were utilized in the refined version of the present research study: Attitude to Mathematical Inquiry and Enjoyment of Mathematics Lessons.

For the factor analyses of WIHIC and TOMRA data, pretest and posttest data were analyzed separately. The only items retained were those that had a factor loading of 0.40 or greater on their own scale and of less than 0.40 on all other scales in the same instrument. Factor analysis results are reported in Chapter 4.

Cronbach's alpha coefficient was used as an index of internal consistency reliability of the WIHIC and TOMRA scales. The discriminant validity of each scale was determined by calculating the mean correlation of each scale with the other scales within the same questionnaire. Finally all of these analyses were implemented at both the individual student and the class levels of analysis.

Analysis of variance (ANOVA) was used to determine the ability of each classroom environment scale to differentiate between the perceptions of students in different classes. The eta^2 statistic was calculated to provide an estimate of the strength of association between class membership and the dependent variable (WIHIC) scales.

Eta^2 is a measure of the proportion of variance accounted for by class membership and is computed by taking the ratio of ‘between’ to ‘total’ sums of squares.

My second research aim was to evaluate whether the exchange-of-knowledge method was more effective than traditional teaching methods in terms of classroom learning environment, student attitudes toward mathematics, and student achievement in mathematics. In order to gauge the effectiveness of using the exchange-of-knowledge method, pretest-posttest changes in classroom environment, attitudes and achievement were examined separately for the small experimental group (n=22) and the large control group (n=490). A pretest-posttest design allowed me to compare the experimental and control groups in terms of changes in learning environment, attitudes and achievement.

For each WIHIC and TOMRA scale, the average item mean, average item standard deviation, and pre-post difference (effect size and results of MANOVA with repeated measures conducted separately for: the set of four WIHIC scales; and for the set of two TOMRA scales and the achievement scale). Because the multivariate tests yielded statistically significant results overall for the set of dependent variables using Wilks’ lambda criterion, the univariate ANOVA for each outcome (environment, attitudes and achievement) was interpreted.

The average item mean is simply the scale mean divided by the number of items in the scale, and is useful when attempting to make meaningful comparisons between scales containing differing numbers of items. The effect size (Thompson, 1998) is the difference between the pretest and the posttest means divided by the pooled standard deviation. Whereas ANOVA provided information about the statistical significance of pre-post differences, effect sizes provided information about the magnitude of these differences.

To check whether associations existed between student perceptions of the learning environment and student attitudes to mathematics, simple correlation and multiple regression analyses were conducted at two levels of the analysis (the student and the class). (Because of the smallness of the sample size for achievement, it wasn't meaningful to investigate associations between classroom environment and achievement.) The simple correlation analysis provided information about the bivariate relationship between each attitude and each learning environment scale. The multiple regression analysis provided a multivariate examination of the influence of correlated learning environment scales on each attitude. The multiple correlation was used to describe the overall association between the whole set of WIHIC scales for each attitude scale, whereas the standardized regression coefficient was used to identify which individual learning environment scales were significantly and independently related to an attitude scale when all of the other learning environment scales were mutually controlled.

An acknowledged weakness of the present design is that the experimental group was so small (n=22) relative to the control group (n=490). Undeniably, it is difficult to generalize the findings from one class using the exchange-of-knowledge method to a broader population. Nevertheless, if large effect sizes could be found for the experimental group, relative to those for the control group, this still would help to provide tentative support for the effectiveness of the exchange-of-knowledge teaching method; see Section 5.3 where this discussion of my study's limitations is taken up again and expanded.

3.7 Conclusion

This chapter described my study's research methods, procedures for collecting data, samples, survey instruments, and how the data were analyzed. The present research study used a quantitative design involving questionnaire surveys. Although 512 students responded to the WIHIC and TOMRA, only the small sample of 22 students in the experimental group provided achievement data.

The schools and student sample (namely, 512 students in 30 classes in 2 schools) were described in this chapter. As well, the choice of the units of statistical analysis and the statistical-analysis procedures employed to answer the research questions were discussed.

Two instruments were utilized for collecting data in this study. The first instrument, that was chosen to measure students' perceptions of their classroom learning environment, was a modified version of the personal form of the What Is Happening In this Class? (WIHIC). The modified version administered in this study consisted of 25 items assessing the five scales of Student Cohesiveness/Cooperation, Teacher Support, Involvement/Investigation, Task Orientation, and Equity (but the Involvement/Investigation scale was lost in subsequent analyses reported in Chapter 4).

Students' attitudes toward mathematics were measured using a modified version of the Test of Mathematics Related Attitude (TOMRA) (Mink & Fraser 2005; Ogbuehi & Fraser, 2007; Spinner & Fraser 2005). The modified version used in this study consisted of 28 items in the five scales of Attitudes to Mathematical Inquiry, Enjoyment of Mathematics Lessons, Social Implications of Mathematics, Leisure Interest in Mathematics and Career Interest in Mathematics (but only the first two of these scales were retained after the analyses reported in Chapter 4).

Cronbach's alpha coefficient was used as a measure of each WIHIC and TOMRA scale's internal consistency reliability. An ANOVA was used to determine whether each WIHIC scale could differentiate between the perceptions of students in different classrooms.

The second research aim involved an evaluation of the exchange-of-knowledge method in terms of achievement, attitudes, and learning environment. A pretest and posttest design was used with a sample size of 490 students in the control groups but only 22 students in the experimental group. Effect sizes (pre-post differences divided by the pooled standard deviation) and significance tests (MANOVA) were used to evaluate the relative effectiveness of the exchange-of-knowledge and traditional teaching methods in terms of changes in environment, attitudes and achievement. Whereas effect sizes provided evidence about the magnitude of differences, MANOVA provided information about the statistical significance of those differences.

Finally, associations between students' perceptions of their classroom environment and student outcomes (attitudes and achievement) were investigated using simple correlation and multiple regression analyses for two levels of analysis (the student and the class).

Chapter 4

DATA ANALYSES AND RESULTS

4.1 Introduction

This chapter is dedicated to reporting the data analyses and results from the questionnaire survey data collected in this study. An essential purpose of this study was to evaluate the relative effectiveness of the exchange-of-knowledge method and traditional teaching methods in terms of students' perceptions of their classroom learning environment, students' attitudes towards mathematics, and achievement in mathematics. A second purpose of this study was to investigate associations between students' outcomes (attitudes and achievement) and their perceptions of the classroom learning environment. Another purpose was to validate widely-applicable instruments for assessing classroom environment and attitudes to mathematics among elementary and middle-school students in Georgia.

Two instruments were administered to a sample of 512 students in 30 grade 5−8 classes: the What Is Happening In this Class? (WIHIC) questionnaire; and the Test of Mathematics Related-Attitudes (TOMRA). The WIHIC questionnaire measures students' perceptions of their classroom environment and the TOMRA assesses students' attitudes toward mathematics. Modified versions of the WIHIC and TOMRA questionnaires were used in the present study only in the English language. Because there were no Spanish-speaking students attending Joseph Martin Elementary or Snelson Golden Middle School at the time of the research, neither the

WIHIC nor the TOMRA needed to be translated into Spanish for questionnaire administration.

Because of the young age of students in my sample, I reduced the original length of the WIHIC from 56 items to 25 items. Whereas the original WIHIC had 56 items in 7 scales, the revised version used in my study had 25 items spread across 5 scales. As discussed in detail in Section 3.4.1 and Table 3.2, the five scales chosen were Student Cohesiveness/Cooperation combined (6 items), Teacher Support (4 items), Involvement/Investigation combined (7 items), Task Orientation (3 items) and Equity (5 items). With this reduction in the number of items, it was important to check whether the *a priori* five-factor structure still applied.

The Test of Science Related Attitudes (TOSRA) – and the parallel version for mathematics, the Test of Mathematics Related Attitudes (TOMRA) – originally were designed with 70 items to assess 7 dimensions of students' attitudes to science or mathematics (Fraser, 1981). A subset of 28 of the original items in 5 scales was selected from TOMRA for use in our study. Although two of the original TOMRA scales were not considered sufficiently salient to include in my study (namely, Normality of Mathematicians and Adoption of Mathematical Attitudes), all of the other five original TOMRA scales were initially included in the questionnaire in my study (Attitude to Mathematical Inquiry, Enjoyment of Mathematics Lessons, Social Implications of Mathematics, Leisure Interest in Mathematics, and Career Interest in Mathematics).

In order to make the questionnaire suitable for mathematics, the word ‘science’ in the original TOSRA is changed to ‘mathematics’ in TOMRA. The TOSRA has been used successfully in numerous past studies of attitudes to science (e.g. Wong & Fraser, 1996), as well as being modified in several past studies (e.g. Mink & Fraser, 2005; Spinner & Fraser, 2005) to focus on mathematics.

Students’ responses to the two instruments were analysed to help to answer the following research questions:

1. Are modified versions of the following widely-applicable instruments for assessing classroom environment and attitudes to mathematics valid when used among elementary and middle-school students in Georgia:
    a. What is Happening In this Class? (WIHIC)
    b. Test of Mathematics Related Attitudes (TOMRA)?

2. Is the exchange-of-knowledge method more effective than traditional teaching methods in terms of :
    a. classroom learning environment
    b. student attitudes toward mathematics
    c. student achievement in mathematics?

3. Are there associations between students’ attitudes and their perceptions of the classroom learning environment?

The structure of Chapter 4 is as follows:

4.2 Validity and Reliability of WIHIC and TOMRA

4.2.1 Factor Structure of WIHIC

4.2.2 Factor Structure of TOMRA

4.2.3 WIHIC's Internal Consistency Reliability, Discriminant Validity and Ability to Differentiate between Classrooms

4.2.4 TOMRA's Internal Consistency Reliability and Discriminant Validity

4.3 Effectiveness of Exchange-of-Knowledge Method: Pretest-Posttest Changes in Classroom Environment, Attitudes, and Achievement for Two Groups

4.4 Associations between Student Attitudes and Classroom Environment

4.5 Limitations, Conclusion and Summary.

4.2 Validity and Reliability of Modified WIHIC and TOMRA

This section reports data analyses and results relevant to the first research question concerning the validity of two questionnaires used in my study, namely, the What is Happening In this Class? (WIHIC) and Test of Mathematics Related Attitudes (TOMRA).

A series of data analyses was initiated to check on the validity of the WIHIC and TOMRA when used with elementary and middle-grade students in Hinesville, Georgia. The analyses attempted to support the factorial validity, internal consistency reliability and discriminant validity of the WIHIC and TOMRA. Also, using ANOVA, I investigated each WIHIC scale's ability to differentiate between the perceptions of students in different classrooms.

As described in Section 3.3, the sample for all of these analyses consisted of 512 students in 30 classes who responded to both the WIHIC and TOSRA as both a pretest and posttest.

4.2.1 Factor Structure of WIHIC

Principal components factor analysis with varimax rotation was used to check the structure of the modified 25-item five-scale version of the WIHIC used in my study (see Table 3.2). To maximize the comprehensiveness of my questionnaire validation efforts, all analyses were performed separately for pretest data and for posttest data. The sample consisted of 512 students from two public schools in the state of Georgia (99 grade 5 students and 413 grade 6–8 students). The two criteria that were used for retaining any item were that it must have a factor loading of at least 0.40 or its own scale and less than 0.40 on all the other WIHIC scales.

Table 4.1 shows that the optimal factor solution for the WIHIC for both the pretest and posttest occurred for 17 items in four scales. The revised scale of Involvement/Investigation was lost altogether. One item was removed from the revised Student Cohesiveness/Cooperation scale. Every item in the revised scales of Teacher Support, Task Orientation and Equity was retained.

TABLE 4.1 Factor Analysis Results for Refined Version of WIHIC (What Is Happening In this Class?) for Pretest and Posttest

Item	Factor Loadings							
	Cohesiveness/ Cooperation		Teacher Support		Task Orientation		Equity	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
SC 1	0.52	0.49						
SC 2	0.64	0.72						
SC 3	–	0.47						
CO 19	0.53	0.58						
CO 20	0.44	0.40						
TS 4			0.66	0.59				
TS 5			0.66	0.61				
TS 6			0.53	0.55				
TS 7			–	0.49				
TO 15					0.56	0.52		
TO 16					0.60	0.41		
TO 17					0.52	0.54		
EQ 21							–	0.57
EQ 22							0.55	0.64
EQ 23							0.65	0.70
EQ 24							0.65	0.71
EQ 25							0.68	0.63
% Variance	7.73	11.28	8.89	7.13	7.14	6.17	29.08	30.84
Eigenvalue	1.31	1.92	1.51	1.21	1.21	1.05	4.95	5.24

The sample consisted of 512 students in 30 classes.
Factor loading smaller than 0.40 have been omitted.
SC = Student Cohesiveness, CO = Cooperation, TS = Teacher Support, TO = Task Orientation, EQ = Equity
Item CO18, as well as all 7 items from the initial Involvement and Investigation scales, were omitted.

Table 4.1 shows that, for most of the 17 items in the refined version of the WIHIC, the factor loading for an item was over 0.40 on its *a priori* scale and less than 0.40 on the other three scales. The only exceptions were Item 3 in the Cohesiveness/Cooperation scale, Item 7 in Teacher Support and Item 21 in Equity, for which the loading of an item on its own scale was less than 0.40 for the pretest. For the posttest data, all 17 items had a factor loading of at least 0.40 on their own scales. For each of the 17 items, Table 4.1 shows that the factor loading for every item was less than 0.40 on all scales except its *a priori* for both the pretest and posttest.

The bottom of Table 4.1 shows that the proportion of variance explained by different WIHIC scales ranged from 7.14% to 29.08% for the pretest and from 6.17% to 30.84% for the posttest. The total proportion of variance explained was 58.05% for the pretest and 55.43% for the posttest. Table 4.1 also shows that the eigenvalues for different scales ranged from 1.21 to 4.95 for the pretest and from 1.05 to 5.24 for the posttest. Overall, the results in Table 4.1 provide strong support for the factorial validity of the refined 17-item four-scale version of the WIHIC.

4.2.2 Factor Structure of TOMRA

A factor analysis similar to that conducted for the WIHIC for the sample of 512 students was also undertaken to check the internal structure of the Test of Mathematics Related Attitudes (TOMRA). As shown in Table 3.4, the revised version of the TOSRA administered in my study has 28 items in five scales. Table 4.2 shows that the optimal factor solution for both the pretest and posttest administrations occurred for a refined 11-item version with the two scales of Attitude to Mathematical Inquiry and Enjoyment of Mathematics Lessons. With only one exception, each of the 11 items in Table 4.2 had a factor loading of over 0.40 on its own scale and less than 0.40 on the other scale for both the pretest and posttest. The exception in that Item 1 in the Attitude to Inquiry scale had a loading of less than 0.40 on its *a priori* scale for the posttest.

The three scales of Social Implications of Mathematics, Leisure Interest in Mathematics, and Career Interest in Mathematics were lost altogether. Also two items were removed from the Enjoyment of Mathematics Lessons scales to improve the factorial validity.

TABLE 4.2 Factor Analysis Results for Refined Version of TOMRA (Test of Mathematics Related Attitudes) for Pretest and Posttest

Item	Factor Loadings			
	Attitude to Inquiry		Enjoyment of Mathematics Lessons	
	Pre	Post	Pre	Post
IN 1	0.44	–		
IN 11	0.47	0.47		
IN 16	0.46	0.44		
IN 23	0.60	0.61		
IN 27	0.44	0.50		
EN 2			0.71	0.82
EN 5			0.59	0.56
EN 8			0.74	0.70
EN 17			0.42	0.49
EN 19			0.77	0.83
EN 24			0.66	0.77
% Variance	34.07	13.67	13.83	38.39
Eigenvalue	3.75	1.50	1.52	4.22

The sample consisted of 512 students in 30 classes.
Factor loadings smaller than 0.40 have been omitted.
IN = Attitude to Inquiry, EN = Enjoyment of Mathematics Lessons
Items EN12 and EN28 were removed from the Enjoyment scale. As well, all items were removed from the Social Implications, Leisure Interest and Career Interest scales.

As well as showing the factor loadings for TOMRA items for the pretest and posttest, Table 4.2 also shows the percentage of variance and eigenvalues for each scale. The bottom of Table 4.2 shows that the proportion of variance explained for the two TOMRA scales was, respectively, 13.83% and 34.07% for the pretest and 13.67% and 38.39% for the posttest. The total amount of the variance for the pretest was 47.90% and was 52.06% for the posttest. The eigenvalue for the two different scales was, respectively, 3.75 and 1.52 for the pretest and 1.50 and 4.22 for the posttest. These results support the factorial validity of my refined version of the TOMRA.

4.2.3 *WIHIC's Internal Consistency Reliability, Discriminant Validity and Ability to Differentiate between Classrooms*

4.2.3.1 *Internal Consistency Reliability*

The internal consistency reliability of a scale is a measure of the extent to which items in that scale measures a common construct. In this study, Cronbach's alpha coefficient was used as an index of internal consistency reliability. Table 4.3 reports the alpha reliability for each of the four scales in the refined version of the WIHIC for two separate units of analysis (the student and the class mean) and separately for the pretest and posttest administrations of the WIHIC. The whole sample of 512 students in 30 classes was used for these analyses.

TABLE 4.3 Internal Consistency (Alpha Reliability Coefficient) and Discriminant Validity (Mean Correlation with Other Scales) for Two Units of Analysis and Ability to Differentiate Between Classrooms (ANOVA Results) for Refined Version of WIHIC for Pretest and Posttest

Scale	No of Items	Unit of Analysis	Alpha Reliability		Mean Correlation with Other Scales		ANOVA Results Eta^2	
			Pre	Post	Pre	Post	Pre	Post
Cohesiveness/ Cooperation	5	Student	0.67	0.70	0.40	0.36	0.12**	0.12**
		Class	0.70	0.76	0.52	0.49		
Teacher Support	4	Student	0.68	0.74	0.39	0.40	0.16**	0.11**
		Class	0.77	0.78	0.56	0.57		
Task Orientation	3	Student	0.61	0.55	0.35	0.32	0.08	0.10**
		Class	0.66	0.71	0.43	0.42		
Equity	5	Student	0.76	0.83	0.42	0.41	0.09**	0.08*
		Class	0.81	0.87	0.53	0.50		

The sample consisted of 512 students in 30 classes.
*$p<0.05$, **$p<0.01$
Eta^2 is the ratio of between to total sums of square and represents the proportion of variance accounted for by class membership.

Table 4.3 shows that the alpha reliability of different WIHIC scales ranged from 0.61 to 0.76 for the pretest and from 0.55 to 0.83 for the posttest with the student as the unit of analysis. At the class level of analysis, the alpha reliability ranged from 0.66

to 0.81 for the pretest and from 0.71 to 0.87 for the posttest for different scales. Generally, reliability coefficients were higher at the class level than at the student level.

4.2.3.2 Discriminant Validity

Discriminant validity is a measure of the extent to which a given scale measures a unique construct that is independent of the constructs measured by other scales in the instrument. Discriminant validity was calculated using the mean correlation of a scale with the other scales as a convenient index. Two units of analysis (the student and the class mean) were used and analyses were conducted separately for pretest and posttest administrations of the WIHIC.

Table 4.3 shows that the mean correlation of a scale with the other scales ranged from 0.35 to 0.42 for the pretest and from 0.32 to 0.41 for the posttest with the student as the unit of analysis. With the class mean as the unit of analysis, the mean correlation for different scales ranged from 0.43 to 0.56 for the pretest and from 0.42 to 0.57 for the posttest. These values suggest that raw scores on the WIHIC assess distinct, but somewhat overlapping, aspects of classroom environment, especially at the class level. However, the factor analysis results attest to the independence of factor scores.

4.2.3.3 Ability to Differentiate Between Classrooms

Another desirable characteristic of any classroom environment scale is that it is capable of differentiating between the perceptions of student in different classes. This characteristic was explored by conducting for each WIHIC scale an ANOVA with the scores on that environment scale as the dependent variable and class membership as the independent variable. Analyses were conducted separately for pretest and posttest data.

The ANOVA results for each WIHIC scale in Table 4.3 show that, for the pretest, the three scales of Cohesiveness/Cooperation, Teacher Support and Equity (but not the Task Orientation scale) were capable of differentiating between classrooms ($p<0.05$). For posttest WIHIC data, all four scales differentiated significantly between classrooms (Table 4.3). The eta^2 statistic – which is the ratio of between the total sums of squares and represents the proportion of variance in scale scores accounted for by class membership – ranged from 0.08 to 0.16 for the pretest data and from 0.08 to 0.12 for the posttest data (Table 4.3).

4.2.4 TOMRA's Internal Consistency Reliability and Discriminant Validity

The internal consistency reliability and discriminant validity also were calculated for the two attitude scales in the refined version of TOMRA for two units of analysis (the student and the class mean). As for the WIHIC, the alpha coefficient was used as the index of internal consistency reliability, and the correlation between the two scales was used as the index of discriminant validity.

Table 4.4 shows that the alpha reliability coefficient for Attitude to Mathematical Inquiry was 0.62 on both the pretest and the posttest at the student level, and was 0.65 for the pretest and 0.64 for the posttest at the class level of analysis. For Enjoyment of Mathematics Lessons, the alpha reliability coefficient was 0.83 for the pretest and 0.86 for the posttest with the student as the unit of analysis, and was 0.88 for the pretest and 0.93 for the posttest at the class level.

TABLE 4.4 Internal Consistency (Alpha Reliability Coefficient) and Discriminant Validity (Correlation with Other Scale) for Two Units of Analysis for Refined Version of TOMRA for Pretest and Posttest

Scale	No. of Items	Unit of Analysis	Alpha Reliability		Correlation with Other Scale	
			Pre	Post	Pre	Post
Attitude to Mathematical Inquiry	5	Student	0.62	0.62	0.36	0.41
		Class	0.65	0.64	0.59	0.62
Enjoyment of Mathematics Lessons	6	Student	0.83	0.86	0.36	0.41
		Class	0.88	0.93	0.59	0.62

The sample consisted of 512 students in 30 classes.

Table 4.4 shows that the correlation between the two attitude scales was 0.36 for the pretest and 0.41 for the posttest with the student as the unit of analysis. With the class mean as the unit of analysis, the correlation between scales was 0.54 for the pretest and 0.62 for the posttest. These values suggest that raw scores on the two attitude scales assess distinct but overlapping aspects of attitude. However the factor analysis reported in Table 4.2 supports the independence of factor scores on these two attitude scales.

4.3 Effectiveness of Exchange-of-Knowledge Method: Pretest-Posttest Changes in Classroom Environment, Attitudes, and Achievement for Two Groups

In order to gauge the effectiveness of using the exchange-of-knowledge method (my second research question), pretest-posttest changes in classroom environment, attitudes and achievement were examined separately for the experimental group and for a control group. For reasons explained in Section 3.3, the experimental group experiencing the exchange-of-knowledge method was quite small (n=22), whereas the control group experiencing traditional teaching methods was relatively large (n-490). Whereas all students responded to the WIHIC and TOSRA, for practical reasons, only the experimental group provided achievement data (based on the teacher-made multiple-choice test described in Section 3.4.3). These are acknowledged shortcomings of my study.

Table 4.5 shows for each scale the average item mean, average item standard deviation, and pre-post difference (effect size and results of MANOVA with repeated measures) conducted separately for: the set of four WIHIC scales; and for the set of two TOMRA scales and the achievement scale). Because the multivariate tests yielded statistically significant results for the instructional group for the set of outcomes using Wilks' lambda criterion, the univariate ANOVA for each individual scale (environment, attitudes and achievement) was interpreted.

The average item mean is simply the scale mean divided by the number of items in the scale, and is useful when making meaningful comparisons between scales containing differing numbers of items. The effect size (Thompson, 1998) is the difference between the pretest and the posttest mean divided by the pooled standard deviation. Whereas the ANOVA provides information about the statistical significance of pre-post differences, the effect size provides information about the magnitude of these differences.

TABLE 4.5 Average Item Mean, Average Item Standard Deviation and Difference Between Pretest and Posttest (Effect Size and ANOVA Results) for WIHIC, TOSRA and Achievement for Experimental and Control Groups

Scale	Group	Average Item Mean		Average Item SD		Difference Between Groups	
		Pre	Post	Pre	Post	Effect Size	*F*
WIHIC							
Cohesiveness/	Exptl	3.05	4.07	0.58	0.48	1.92	2.49**
Cooperation	Control	3.83	3.88	0.70	0.69	0.10	1.10
Teacher Support	Exptl	2.66	4.53	0.90	0.31	3.12	2.91**
	Control	3.82	3.88	0.70	0.69	0.09	1.15
Task Orientation	Exptl	3.32	4.14	0.79	0.61	1.17	2.26*
	Control	3.88	3.90	0.82	0.75	0.02	0.56
Equity	Exptl	3.33	4.23	0.69	0.62	1.38	2.29**
	Control	3.95	3.94	0.77	0.81	0.01	0.42
TOMRA							
Attitude to Inquiry	Exptl	3.10	3.51	0.73	0.55	0.63	1.43**
	Control	3.33	3.31	0.81	0.76	0.02	0.60
Enjoyment of	Exptl	2.95	3.77	1.06	0.77	0.88	1.94*
Mathematics	Control	3.10	3.07	0.96	0.99	0.04	0.83
Lessons							
Achievement [a]	Exptl	4.54	6.35	1.11	1.51	1.39	2.41**

The sample size was 22 students in the experimental group and 490 students in the control group.
**p*<0.05, ***p*<0.01
[a] The control group did not respond to the achievement test. Achievement scores have been divided by 10.

The results in Table 4.5 show striking differences between the experimental and the control groups in terms of the magnitudes of pretest-posttest changes. For the four classroom environment and two attitude scales, the control group experienced pretest-posttest changes that were both statistically nonsignificant and small in magnitude (ranging from only 0.01 to 0.10 standard deviations). In contrast, the experimental group experienced pretest-posttest changes on these six classroom environment and attitude scales that were statistically significant and large in magnitude (ranging from 0.63 to 3.12 standard deviations). Although the control group did not respond to the achievement test, Table 4.5 shows that pretest-posttest changes in achievement for the experimental group were statistically significant and large in magnitude (namely, 1.39 standard deviations).

Acknowledged weaknesses of the design of this study are that the experimental group was so small (n = 22) relative to the control group (n = 490), and that only the experimental group provided achievement data. Admittedly, it is difficult to generalize the findings from one class using the exchange-of-knowledge method to a broader population. Nevertheless, the very large effect sizes for the experimental group, relative to those for the control group, still provide strong but tentative support for the effectiveness of the exchange-of-knowledge teaching method. Clearly, the promising but tentative findings from my study need to be replicated in future research.

4.4 Associations Between Student Attitudes and Classroom Environment

To examine associations between students' attitudes to mathematics and their perceptions of the learning environment (my third research question), simple correlation and multiple regression analyses were conducted. Whereas the simple correlation analysis provided information about the bivariate association between each attitude and each individual environment dimension, the multiple regression analysis provided a more parsimonious picture of the joint influence of a set of correlated environment scales on attitudes. Through examination of regression coefficients, it was possible to ascertain the unique contribution of a particular environment scale to variance in attitude scores when the other environment scales were mutually controlled.

Analyses were conducted separately for pretest and posttest data and separately for two units of analysis (the student and the class mean) for the sample of 512 students. Although associations were investigated for each attitude scale (Inquiry and Enjoyment), the smallness of the sample size (n = 22) for achievement meant that it could not be included in these analyses.

The results in Table 4.6 show that the number of statistically significant simple correlations (p<0.05) was 10 with the student as the unit of analysis, but only one with the class mean as the unit of analysis. Cohesiveness/Cooperation was significantly correlated with both Attitude to Mathematical Inquiry and Enjoyment of Mathematics Lessons on both the pretest and posttest at the student level of analysis. Moreover, for class means, Cohesiveness/Cooperation also was significantly correlated with Enjoyment of Mathematics Lessons on the posttest. With the student as a unit of analysis and for the posttest, a statistically significant simple correlation was found between each attitude scale (Inquiry and Enjoyment) and each of the three WIHIC scales of Teacher Support, Task Orientation and Equity.

The bottom of Table 4.6 shows the value obtained for the multiple correlation between the set of four WIHIC scales and each attitude scale on the pretest and the posttest for each unit of analysis (the student and the class mean). The only case for which the multiple correlation was statistically significant was for posttest scores on the Enjoyment of Mathematics Lessons scale at the student level of analysis (R =

0.19, $p<0.01$). In order to identify which WIHIC scale(s) explained the significant multiple correlation between Enjoyment posttest cores and classroom environment, the standardized regression coefficients reported in Table 4.6 were examined. This table shows that Task Orientation was a significant independent predictor of posttest Enjoyment scores when the other three WIHIC scales were mutually controlled.

TABLE 4.6 Simple Correlation and Multiple Regression Analyses for Associations Between Attitudes and Learning Environment for Two Units of Analysis for Pretest and Posttest

Scale	Unit of Analysis	Simple Correlation				Standardized Regression Coefficient			
		Inquiry		Enjoyment		Inquiry		Enjoyment	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Cohesiveness /Cooperation	Student	0.09*	0.14**	0.11**	0.16**	0.12	0.09	0.10	0.11
	Class	0.08	0.20	0.18	0.41*	0.01	0.09	0.19	0.40
Teacher Support	Student	-0.01	0.09*	0.05	0.10*	-0.04	-0.03	-0.01	0.02
	Class	0.19	0.17	0.07	0.24	0.11	-0.06	-0.26	-0.03
Task Orientation	Student	0.01	0.11*	0.07	0.15**	-0.02	0.04	0.03	0.11*
	Class	-0.06	0.30	0.09	0.20	-0.18	0.25	-0.03	0.05
Equity	Student	0.00	0.14**	0.06	0.11**	-0.02	0.11	0.01	0.03
	Class	0.22	0.19	0.22	0.20	0.20	0.09	0.33	0.01
Multiple Correlation, *R*	Student					0.10	0.18	0.11	0.19**
	Class					0.28	0.32	0.29	0.41

The sample consisted of 512 students in 30 classes.
$*p<0.05$, $**p<0.01$

It is noteworthy that every statistically significant attitude-environment association in Table 4.6 is positive. This replicates considerable past research that has established positive relationships between classroom environment and student attitudes (Fraser, 1994, 1998a, 2007; Wong & Fraser, 1996).

4.5 Limitations, Conclusions and Summary

There were several limitations to my study, including the high turnover of students in the middle of the school year because Hinesville, Georgia is a military town. Fort Stewart is located in Hinesville and parents were being deployed overseas. Some parents decided to return back home until their spouses came home from their deployment, thus withdrawing their children from Liberty County School system in the middle of the school year. Also, students transferred in and out of the school because of parents moving in and out of the area.

The present study involved the administration of two modified questionnaires, the WIHIC (What Is Happening In this Class?) questionnaire and the TOMRA (Test of Mathematics Related Attitude), both as pretests and posttests. The WIHIC questionnaire was used to assess students' perceptions of four dimensions of their classroom learning environment and the TOMRA was used to assess five aspects of students' attitudes to mathematics. The data were collected from 512 boys and girls in 30 classes. One of these classes (22 students) comprised an experimental group which experienced the exchange-of-knowledge method of teaching, whereas the remaining 29 classes (490 students) experienced traditional teaching/learning methods. This chapter has presented the analyses and results for the data collected for the present study.

To examine the validity of the WIHIC and TOMRA, factor analyses, internal consistency reliability, discriminant validity and ANOVA for class membership differences were explored separately for pretest and posttest data. A series of principal components factors analyses resulted in the acceptance of an optimal version of WIHIC encompassing 17 items in four scales and an optimal version of TOMRA encompassing 11 items in two scales. The scales in the refined version of the WIHIC were Student Cohesiveness/Cooperation, Teacher Support, Task Orientation and Equity were retained. All items from my initial

Involvement/Investigation scales, as well as one item from Cohesiveness/Cooperation, were omitted.

For most of the 17 items in the refined version of the WIHIC, the factor loading for an item was over 0.40 on its *a priori* scale and less than 0.40 on the other three scales. With only one exception, each of the 11 items has a factor loading of over 0.40 on its own scale and less than 0.40 on the other scale for both the pretest and posttest.

For WIHIC scales, the proportion of variance explained by different scales ranged from 7.14% to 29.08% for the pretest and from 6.17% to 30.84% for the posttest. The total proportion of variance explained was 58.05% for the pretest and 55.43% for the posttest. The eigenvalues ranged from 1.21 to 4.95 for the pretest and from 1.05 to 5.24 for the posttest. For the TOMRA, the total proportion of variance accounted for by the two scales was 47.90% and 52.06%, respectively, for pretest and posttest data.

The alpha reliability of different WIHIC scales ranged from 0.61 to 0.76 for the pretest and from 0.55 to 0.83 for the posttest with the student as the unit of analysis. At the class level of analysis, the alpha reliability ranged from 0.66 to 0.81 for the pretest and from 0.71 to 0.87 for the posttest for different scales. Generally, reliability coefficients were higher at the class level than at the student level. The internal consistency reliability and discriminant validity also were investigated for the two attitude scales from TOMRA for two units of analysis. The alpha reliability coefficient for Attitude to Mathematical Inquiry was 0.62 on both the pretest and the posttest at the student level, and was 0.65 on the pretest and 0.64 on the posttest at the class level.

The discriminant validity was calculated using the mean correlation of a scale with the other scales as a convenient index. The discriminant validity results for the WIHIC showed that the mean correlation of a scale with the other scales ranged from 0.35 to 0.42 for the pretest and from 0.32 to 0.41 for the posttest with the student as the unit of analysis. With the class mean as the unit of analysis, the mean correlation for different scales ranged from 0.43 to 0.56 for the pretest and from 0.42 to 0.57 for the posttest. For the TOMRA, the correlation between the two attitude scales was 0.36 for the pretest and 0.41 for the posttest with the student as the unit of analysis. With the class mean as the unit of analysis, the correlation between scales was 0.54 on the pretest and 0.62 on the posttest.

The results of the analysis of variance (ANOVA) for the data obtained from the WIHIC questionnaire (see Table 4.3) indicate that each WIHIC scale differentiated significantly between classrooms for the pretest and for the posttest. The eta^2 statistic, which is the ratio of between the total sums of squares and represents the proportion of variance in scale scores accounted for by class membership, ranged from 0.08 to 0.16 for the pretest data and from 0.08 to 0.12 for the posttest data.

Overall these results suggest that modified versions of both the WIHIC questionnaire and the TOMRA were valid and reliable instruments for the assessment of, respectively, students' perceptions of their psychosocial classroom environment and their attitudes toward mathematics among elementary and middle-school students in Georgia.

In several studies in the USA, original, modified, and/or translated versions of the WIHIC have been validated and found to be reliable in Miami (Allen & Fraser 2007), New York (Wolf & Fraser, 2008) and California (Ogbuehi & Fraser, 2007). The WIHIC's validity and reliability also have been established in other countries such as Australia and Taiwan (Aldridge, Fraser & Huang, 1999), Singapore Chionh & Fraser, 2009), Canada (Zandvliet & Fraser, 2004), Korea (Lee & Fraser, 2001) and Indonesia (Fraser, Aldridge & Adolphe, 2010).

Various versions of TOSRA/TOMRA have been cross-validated and applied in numerous studies around the world. For example, modified version of the TOSRA and TOMRA have been successfully validated and in previous studies in Singapore (Goh, 1994; Goh & Fraser, 1998; Wong & Fraser, 1996), the USA (Allen & Fraser, 2007; Ogbuehi & Fraser, 2007) and Indonesia (Fraser, Aldridge & Adolphe, 2010).

In order to answer my second research question about whether the exchange-of-knowledge method is more effective than the traditional teaching methods in terms of classroom learning environment, student attitudes toward mathematics, and student achievement in mathematics, pretest-posttest changes were examined separately for the small experimental group (n = 22) and the large control group (n = 490). Pre-post changes on these scales were explored using effect sizes and the results of MANOVA with repeated measures. Because the multivariate test yielded statistically significant results for the set of outcomes using Wilks' lambda criterion, the univariate ANOVA for each outcome (environment, attitudes and achievement) was interpreted.

Striking differences were found between the experimental and the control groups in terms of the magnitudes of pretest-posttest changes. For the four classroom environment and two attitude scales, the control group experienced pretest-posttest changes that were both statistically nonsignificant and small in magnitude (ranging from only 0.01 to 0.10 standard deviations). In contrast, the experimental group experienced pretest-posttest changes on these six classroom environment and attitude scales that were statistically significant and large in magnitude (ranging from 0.63 to 3.12 standard deviations). Although the control group didn't provide achievement data, large and significant pre-post changes in achievement (of 1.39 standard deviations) were observed for the experimental group.

To examine associations between students' attitudes to mathematics and their perceptions of the learning environment, simple correlation and multiple regression analyses were conducted. Whereas the simple correlation analysis provided information about bivariate associations between an attitude and an individual environment dimension, the multiple regression analysis provided a more parsimonious picture of the joint influence of a set of correlated environment scales on attitudes. The number of statistically significant simple correlations ($p < 0.05$) was 10 with the student as the unit of analysis, but only one with the class mean as the unit of analysis. Cohesiveness/Cooperation was significantly correlated with both Attitude to Inquiry and Enjoyment of Mathematics Lessons for both the pretest and posttest at the student level of analysis. Moreover, for class means, Cohesiveness/Cooperation also was significantly correlated with Enjoyment of Mathematics Lessons on the posttest. With the student as a unit of analysis and for the posttest, a statistically significant simple correlation was found between each attitude scale (Inquiry and Enjoyment) and each of the three WIHIC scales of Teacher Support, Task Orientation and Equity. Only one significant multivariate association (between Task Orientation and Enjoyment) was found. Overall, the present findings of positive associations between students' attitudes and their perceptions of their classroom learning environment replicate considerable prior research in a range of countries (Chionh & Fraser, 2009; Fraser, 1994, 1998a, in press; Wong & Fraser, 1996).

This study adds to the field of learning environments as it is one of only a few that has used learning environment perceptions as process criteria in the evaluation of educational innovations in mathematics. In fact, my study was the first to evaluate the exchange-of-knowledge method using learning environment criteria. Past research was replicated in that the What Is Happening In this Class? (WIHIC) questionnaire exhibited satisfactory factorial validity and internal consistency reliability with grade 5–8 mathematics students in Georgia. Also associations were found between classroom environment and students' attitudes to mathematics. It is especially noteworthy that the exchange-of-knowledge method was found to be more effective than traditional teaching methods, especially in terms of classroom environment and student attitudes toward mathematics.

Chapter 5

DISCUSSION AND CONCLUSION

5.1 Introduction

Mathematics has often been a misunderstood subject by many and considered to be understood by a gifted few. In order for students to understand mathematics, they need to make mathematical connections with real-world situations in order to understand the essence of mathematics. According to Battista (1999), educators must analyze the issues that are relevant to the reform of mathematics education from a scholarly perspective that undergirds the reform movement and is based on current research on mathematics learning. My study investigated the effectiveness of the exchange-of-knowledge method for grade 5−8 students in terms of classroom learning environment, student attitudes toward mathematics and student achievement in mathematics.

In this chapter, I provide a summary and discussion based on my research which relied on data from two questionnaires, namely, the What Is Happening In this Class? (WIHIC) and the Test of Mathematics-Related Attitudes (TOMRA). The sample consisted of 512 students in 30 grade 5−8 classes, with the majority of the sample in a control group experiencing traditional teaching methods and the minority in an experimental group following the exchange-of-knowledge method. Also mathematics achievement was assessed for the experimental group.

The significance of this study is that it adds to the field of learning environments because it modified and validated questionnaires and assessed grade 5–8 students' perceptions of the mathematics classroom learning environments, investigated the effectiveness of a promising teaching method, and explored associations between the learning environment and students' achievement and attitudes in mathematics classrooms. No previous study has employed a learning environment framework for investigating the exchange-of-knowledge teaching method.

Chapter 5 consists of the following headings:

- Synopsis of Each Chapter of This Thesis (Section 5.2)
- Constraints of the Study (Section 5.3)
- Uniqueness and Contributions of the Study (Section 5.4)
- Suggestions for Future Research (Section 5.5)
- Conclusion (Section 5.6).

5.2 Synopsis of Each Chapter in This Thesis

Chapter 1 introduced my study into the effectiveness of using the exchange-of-knowledge method to enhance achievement, attitudes and classroom environment in grade 5 mathematics. The first chapter also established the objectives of the study and provided information about the study's background, significance, context and rationale. The following research questions were identified:

1. Are modified versions of widely-applicable instruments for assessing classroom environment and attitudes to mathematics valid when used among elementary and middle-school students in Georgia:
   a. What Is Happening In this Class? (WIHIC)
   b. Test of Mathematics Related Attitudes (TOMRA)?

2. Is the exchange-of-knowledge method more effective than traditional teaching methods in terms of:
   a. classroom learning environment
   b. student attitudes toward mathematics
   c. student achievement in mathematics ?

3. Are there associations between students' outcomes (attitudes and achievement) and their perceptions of the classroom learning environment?

Chapter 1 also described mathematics education in Georgia, including information pertaining to the population in terms of the distribution of socioeconomic levels in Liberty County, Georgia, where my research was conducted. As well, the chapter provided historical perspectives on the field of classroom learning environments, as well as a brief overview of each chapter in the thesis.

Chapter 2 reviewed literature in several areas such as: traditional and constructivist approaches to mathematics teaching techniques; the exchange-of-knowledge method; learning environment instruments and research; and attitudes to mathematics.

Because the field of classroom learning environments provided a foundation for my study, various classroom environments instruments were reviewed in Chapter 2, such as the Learning Environment (LEI), Classroom Environment Scale (CES), My Class Inventory (MCI), Constructivist Learning Environment Survey (CLES), Individualized Classroom Environment (ICEQ), and Questionnaire on Teacher Interaction (QTI). The What Is Happening In this Class? (WIHIC) questionnaire was chosen for use in my study, and so literature on the WIHIC was reviewed in detail.

Because the purposes of the present study included evaluating the exchange-of-knowledge method in terms of student attitudes and probing relationships between classroom learning environments and attitudes toward mathematics, literature related to attitudes also was reviewed in Chapter 2. In particular, the Test of Science Related Attitudes, which was modified to the Test of Mathematics Related Attitudes (TOMRA), was used in my study and so it was discussed in detail.

Because a major focus of the present study was to evaluate whether the exchange-of-knowledge method was more effective than traditional teaching methods in terms of classroom learning environment, student achievement and student attitudes towards mathematics, a review was provided in Chapter 2 of past research in which learning environment dimensions have been employed as criterion variables in the evaluation of educational programs and innovations.

The research methods chapter (Chapter 3) described procedural phases of the present study, which involved collecting quantitative data using questionnaire surveys using a pretest and posttest design. In particular, modified versions of the WIHIC and

TOMRA were used to assess, respectively, students' perceptions of classroom environment and attitudes to mathematics. The nature of the modification made to the WIHIC and TOSRA, to make them more suitable for younger respondents, were outlined. The choice of instruments, the grade level and the school for the research were discussed and justified. Details of the student sample (512 students in 30 classes) were also provided in this chapter.

Statistical-analysis procedures were outlined in Chapter 3 for each of my three research questions. For the validation of the learning environment and attitude questionnaires, factor analysis was performed separately for pretest and posttest data. Only items with a factor loading of at least 0.40 on their own scale and less than 0.40 on all other scales were retained. Cronbach's alpha coefficient was used as an index of the internal consistency reliability of each scale. The independence or discriminant validity of scales was checked using the mean correlation of a scale with the other scales. For each learning environment scale, an ANOVA was performed to check whether it was capable of differentiating between the perceptions of students in different classrooms. The eta^2 statistic – which is the ratio of between sums of squares to total sums of squares – was used to represent the proportion of variance in scale scores accounted for by class membership.

To explore bivariate and multivariate associations between learning environments and attitudes, the two methods of statistical analysis chosen were simple correlation analysis and multiple regression analysis. Regression coefficients were used to identify which learning environment scales uniquely accounted for variance in a student outcome when the other learning environment scales were mutually controlled.

MANOVA, followed by an individual ANOVA for each individual environment, attitude and achievement scale, were used to investigate differences between the two instructional. In addition, effect sizes were used to describe the magnitude of the differences between the two instructional groups in standard deviation units.

Chapter 4 reported the findings for my three research questions. The data collected from my sample of 512 students in 30 classes in Liberty County were analyzed in different ways to examine the validity and reliability of the modified 25-item five-scale version of the WIHIC and the 28-item five-scale version of the TOMRA to address research question 1. Principal components factor analysis followed by varimax rotation led to the acceptance of a revised version of the classroom environment instrument involving 17 items in the four scales of Cohesiveness/Cooperation, Teacher Support, Task Orientation and Equity. For nearly all of the 17 items in the final version of the WIHIC for the pretest and posttest, the factor loading was over 0.40 on its a priori scale and less than 0.40 on the other three scales. The factor loading was less than 0.40 on all scales except its a priori scale for both the pretest and posttest.

For the TOMRA, a similar separate factor analysis for pretest and posttest data led to a two-factor solution with a total of 11 items in the two scales of Attitude to Mathematical Inquiry and Enjoyment of Mathematics Lessons. For each of these 11 items, the factor loading was more than 0.40 on its own scale and less than 0.40 on the other scale.

The internal consistency reliability (Cronbach alpha coefficient) was calculated for each of the four scales of the WIHIC and the two attitude scales for two units of analysis (student and class). Using the student as the unit of analysis, scale reliability estimates ranged from 0.67 to 0.76 for the pretest and from 0.55 to 0.83 for the posttest. Using the class mean, the reliability of the different WIHIC scales ranged from 0.66 to 0.81 for the pretest and from 0.70 to 0.81 for the posttest. The alpha reliability coefficient for Attitude to Mathematical Inquiry was 0.62 for both the pretest and the posttest at the student level, and was 0.65 for the pretest and 0.64 for the posttest at the class level of analysis. For Enjoyment of Mathematics Lessons, the alpha reliability coefficient was 0.83 for the pretest and 0.86 for the posttest with the student as the unit of analysis, and was 0.88 for the pretest and 0.93 for the posttest at the class level.

For the WIHIC, the mean correlation of a scale with the other scales (a convenient measure of scale independence or discriminant validity), ranged from 0.35 to 0.42 for the pretest and from 0.32 to 0.41 for the posttest with student as the unit of analysis. With the class mean as the unit of analysis, the mean correlation ranged from 0.43 to 0.56 for the pretest and from 0.42 to 0.57 for the posttest. The correlation between the two attitude scales was 0.36 for the pretest and 0.41 for the posttest with the student as the unit of analysis. With the class mean as the unit of analysis, the correlation between scales was 0.54 on the pretest and 0.62 on the posttest. These values suggest that raw scores on the four WIHIC scales and two attitude scales assess distinct but overlapping aspects of attitude. However the factor analysis reported in Chapter 4 attests to the independence of factor scores on these two instruments.

An analysis of variance (ANOVA) was used to determine the ability of each WIHIC scale to differentiate between the perceptions of the students in different classes. The eta^2 statistic was calculated to provide an estimate of the strength of association between class membership and the dependent variable (WIHIC scale). Each scale differentiated significantly between classes except for Task Orientation for the pretest. For the posttest, all four scales differentiated significantly ($p<0.5$) between classrooms. The proportion of variance in scale scores accounted for by class membership ranged from 0.08 to 0.16 for the pretest data and from 0.08 to 0.12 for the posttest data.

My research objective 2 was:

> Is the exchange-of-knowledge method more effective than traditional teaching methods in terms of:
>
> a. classroom learning environment
> b. student attitudes toward mathematics
> c. student achievement in mathematics?

For my research objective 2, the relative effectiveness of the exchange-of-knowledge method and traditional instructional methods was examined in terms of pretest-posttest changes for the small experimental group and the large control group in terms of classroom environment and student outcomes. MANOVA and ANOVAs were used to provide information about the statistical significance of the pre-post differences, whereas effect sizes provided information about the magnitude of these pretest-posttest changes expressed in standard deviation units. For the four classroom environments and the two attitude scales, the control group experienced pretest-posttest changes that were both statistically nonsignificant and small in magnitude (ranging from 0.01 to 0.10 standard deviations). However, the experimental group experienced pretest-posttest changes on six classroom environment and attitude scales that were statistically significant and large in magnitude (ranging from 0.63 to 3.12 standard deviations). The pretest-posttest changes in achievement were available only for the experimental group, but they were statistically significant and large in magnitude (namely, 1.39 standard deviations).

Simple correlation and multiple regression analysis were used to address the third and final research question regarding associations between students' attitudes and their perceptions of the classroom learning environment. These associations were strong and positive. The number of statistically significant simple correlations ($p<0.05$) was 10 with the students as unit of analysis, but was only one with the class mean as unit of analysis. Cohesiveness/Cooperation was significantly correlated with both Attitude to Mathematical Inquiry and Enjoyment of Mathematics Lessons for both the pretest and posttest at the student level. In addition, for class means, Cohesiveness/Cooperation also was significantly correlated with Enjoyment of Mathematics Lessons on the posttest.

The multiple correlation between the set of four WIHIC scales and each attitude scale for the pretest and the posttest for each unit of analysis (the student and the class mean) was calculated. The only case for which the multiple correlation was statistically significant was for posttest scores for the Enjoyment of Mathematics Lessons scale at the student level of analysis. In order to identify which WIHIC scale(s) explained the significant multiple correlation between posttest scores on Enjoyment of Mathematical Lessons and classroom environment, standardized regression coefficients were examined. Task Orientation was a significant independent predictor of posttest Enjoyment scores when the other three WIHIC scales were mutually controlled.

5.3 Constraints of the Study

As with all educational research, the results from my study need to be interpreted with caution because of the study's limitations. In interpreting the results from the present study, several factors should be contemplated:

1. One of the acknowledged weaknesses of this study is that the experimental group was so small (n=22) compared to the control group (n=490). It is difficult to generalize the findings from one class using the exchange-of-knowledge method to a broader population. Therefore, it is not clear whether the findings from the present study can be generalized more widely beyond the specific sample involved.
2. Because only the experimental group provided achievement data, my findings pertaining to achievement are less dependable than those pertaining to classroom environment and attitudes.
3. There was a high turnover of students in the middle of the year because Hinesville is a military town. Because parents were being deployed overseas,

they moved their dependents back home, or some military personnel received orders to relocate to Hinesville. Thus, students were withdrawing from and registering into Liberty County School system throughout the school year. Because of the socioeconomic background of the majority of the students (a Title One school), parents were moving in and out of the district. These factors led to a reduction in my sample size.

4. The students involved in my study were not typical of students found in average elementary and middle schools. The majority of the students were at-risk and were reading below grade level. Most students came from diverse backgrounds, various maturational stages, different ethnic and cultural groups, and low socioeconomic backgrounds. As a result, my findings might not be able to be generalized to other more typical groups of students.
5. This study could have provided more insightful information if qualitative data-collection methods had been used in conjunction with quantitative data-gathering methods as recommended by Tobin and Fraser (1998). The use of qualitative methods could have complemented the quantitative methods to yield a deeper understanding of the efficacy of the exchange-of-knowledge method.

5.4 Uniqueness and Contributions of the Study

The present study is unique in that it is one of a relative few that has used learning environment perceptions as process criteria in the evaluation of educational innovations in mathematics, and the only study ever of the learning environment associated with the exchange-of-knowledge method. Therefore my study not only adds to the area of research that pertains to the effectiveness of the exchange-of-knowledge method, but also it contributes to the field of learning environments research. Another important contribution of the study was to validate, and make available to other researchers and teachers, widely-applicable questionnaires for assessing classroom environment and student attitudes to mathematics among elementary and middle-school students in Georgia.

My evaluation of the exchange-of-knowledge method has practical implications for educators. Despite some acknowledged weaknesses in my study's design, the very large effect sizes for changes in learning environment and attitude scores (ranging from 0.63 to 3.12 standard deviations) for students experiencing the exchange-of-knowledge method support the method's effectiveness. In the light of these strong but tentative findings, other students are likely to benefit from their teachers' use of the exchange-of-knowledge method in mathematics.

The present study's findings of positive associations between students' attitudes to mathematics and the learning environment also provide potentially practical implications that administrators and teachers could perhaps utilize to improve their students' attitudes. Based on my study, it is likely that students' Attitudes to Mathematical Inquiry and their Enjoyment of Mathematics Lessons can be enhanced by creating classroom environments with greater Cohesiveness/Cooperation, Teacher Support, Task Orientation and Equity.

5.5 Suggestions for Future Research

The What Is Happening In this Class? (WIHIC) questionnaire and Test of Mathematics Related Attitudes (TOMRA) were found to be cost-effective, valid, adaptable, and reliable instruments that can be used with confidence in the elementary and middle-school settings. Therefore, in future research, these instruments could be used in evaluating other curricula. The range of potential future applications includes various academic subjects at different grade levels at the elementary, middle-school and secondary-school levels. Based on past research involving classroom environment instruments (Fraser, 1998a, in press), the WIHIC could be used to evaluate other educational innovations in mathematics and to guide improvements in the classroom environments.

Future research should incorporate structured interviews and other qualitative data-collection techniques, as suggested by Fraser and Tobin (1991), in addition to questionnaires. According to Tobin and Fraser (1998), combining qualitative and quantitative research methods can help to provide a clearer understanding of the learning environment and enhance the information obtained from quantitative methods alone. The use of the combination of qualitative and quantitative methods in the future is likely to enrich findings from the research.

Because of the restricted size of my experimental group and the restricted representativeness of my sample, it will be important in future research to replicate my study with larger and more representative samples. Such studies would increase confidence in, and the generalizability of, my promising but tentative findings.

5.6 Conclusion

As we continue to strive for academic excellence in the 21st century, I hope that my study will make a positive contribution in the field of learning environments. The findings of the present research study add to and supplement past and recent learning environment studies (Allen & Fraser, 2007; Chionh & Fraser, 2009; Fraser, 1994, 1998, in press; Goh & Khine, 2002; Ogbuehi & Fraser, 2007). Specifically, as in past studies (Lightburn & Fraser, 2007; Maor & Fraser, 1996; Teh & Fraser, 1994), classroom learning environment assessments were among the criteria used for evaluating the use of the exchange-of-knowledge method in my study.

Additionally, a broader and larger sample of students than was used in my study is desirable in future research in order to render more dependable findings regarding the effectiveness of the exchange-of-knowledge approach and the influence of the learning environment on student attitudes and achievement. It would be advantageous and worthwhile to investigate, for a larger sample size and a wider variety of student outcomes, the effectiveness of the exchange-of-knowledge method.

Academic excellence and teacher accountability are common goals globally that we all strive to attain. Past and recent research including my own could unlock the mystery that surrounds students' mathematical academic success. Use of the exchange-of-knowledge method has the potential to lead to improvements in classroom environments and student outcomes in mathematics and other subjects.

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APPENDIX A

What Is Happening In this Class? (WIHIC)

DIRECTIONS

1. This questionnaire contains 25 statements about your mathematics class. You will be asked what you think about these statements. There are no ‘right’ or ‘wrong’ answers. Your opinion is what is wanted.

2. For each statement, draw a circle around:

   SA if you **STRONGLY AGREE** with the statement
   A if you **AGREE** with the statement
   N if you are **NOT SURE**
   D if you **DISAGREE** with the statement
   SD if you **STRONGLY DISAGREE** with the statement.

3. *Practice Item*

   0 It would be interesting to learn about boats.

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

   0 SA A N D SD

4. If you change your mind about an answer, cross it out and circle another one.

5. Although some statements in this questionnaire are fairly similar to other statements, you are asked to indicate your opinion about all statements.

This questionnaire is based on the TOSRA/TOMRA, which was developed by Fraser (1981). It was modified and used in my study and included in this thesis with the permission of the authors.

	STRONGLY AGREE	AGREE	NOT SURE	DISAGREE	STRONGLY DISAGREE
1. I am friendly to members of this class. (SC)	SA	A	N	D	SD
2. I work well with other class members. (SC)	SA	A	N	D	SD
3. I help other class members who are having trouble. (SC)	SA	A	N	D	SD
4. The teacher goes out of his/her way to help me. (TS)	SA	A	N	D	SD
5. The teacher helps me when I have trouble with the work. (TS)	SA	A	N	D	SD
6. The teacher moves about the class and talks with me. (TS)	SA	A	N	D	SD
7. The teacher's questions help me to understand. (TS)	SA	A	N	D	SD
8. I discuss ideas in class. (INV)	SA	A	N	D	SD
9. The teacher asks me questions. (INV)	SA	A	N	D	SD
10. I ask the teacher questions. (INV)	SA	A	N	D	SD
11. Students discuss with me how to go about solving problems. (INV)	SA	A	N	D	SD
12. I am asked to explain how I solve problems. (INV)	SA	A	N	D	SD
13. I explain the meaning of statements, diagrams, and graphs. (IV)	SA	A	N	D	SD
14. I find out answers to questions by doing investigations. (IV)	SA	A	N	D	SD
15. Getting a certain amount of work done is important to me. (TO)	SA	A	N	D	SD
16. I set goals for this class. (TO)	SA	A	N	D	SD
17. I pay attention during this class. (TO)	SA	A	N	D	SD
18. I share my books and resources with other students when doing assignments. (CO)	SA	A	N	D	SD
19. When I work in groups in this class, there is teamwork. (CO)	SA	A	N	D	SD
20. I learn from other students in this class. (CO)	SA	A	N	D	SD
21. The teacher gives as much attention to my questions as to other students' questions. (EQ)	SA	A	N	D	SD
22. I am treated the same as other students in this class. (EQ)	SA	A	N	D	SD
23. I receive the same encouragement from the teacher as other students do. (EQ)	SA	A	N	D	SD
24. I get the same opportunity to contribute to class discussions as other students do. (EQ)	SA	A	N	D	SD
25. I get the same opportunity to answer questions as other students. (EQ)	SA	A	N	D	SD

SC Student Cohesiveness, TS Teacher Support, INV Involvement, IV Investigation, TO Task Orientation, CO Cooperation, EQ Equity

APPENDIX B

Test of Mathematics Related Attitudes (TOMRA)

DIRECTIONS

1. This questionnaire contains 28 statements about your mathematics class. You will be asked what you think about these statements. There are no ‘right’ or ‘wrong’ answers. Your opinion is what is wanted.

2. For each statement, draw a circle around:

   SA if you **STRONGLY AGREE** with the statement
   A if you **AGREE** with the statement
   N if you are **NOT SURE**
   D if you **DISAGREE** with the statement
   SD if you **STRONGLY DISAGREE** with the statement.

3. *Practice Item*

   1 It would be interesting to learn about boats.

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

   1 SA A N D SD

6. If you change your mind about an answer, cross it out and circle another one.

7. Although some statements in this questionnaire are fairly similar to other statements, you are asked to indicate your opinion about all statements.

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	STRONGLY AGREE	AGREE	NOT SURE	DISAGREE	STRONGLY DISAGREE
1. I would prefer to find out why something happens by doing an experiment. (+ Inquiry)	SA	A	N	D	SD
2. Mathematics lessons are fun. (+ Enjoyment)	SA	A	N	D	SD
3. I would like to belong to a mathematics club. (+ Leisure)	SA	A	N	D	SD
4. Mathematics is man's worse enemy. (- Social)	SA	A	N	D	SD
5. I dislike mathematics lessons. (- Enjoyment)	SA	A	N	D	SD
6. I get bored when watching mathematics programs on TV at home. (- Leisure)	SA	A	N	D	SD
7. When I leave school, I would like to work with people who make discoveries in mathematics.(+ Career)	SA	A	N	D	SD
8. Schools should have more mathematics lessons each week. (+ Enjoyment)	SA	A	N	D	SD
9. I would like to be given a mathematics book or a piece of mathematics equipment as a present. (+ Leisure)	SA	A	N	D	SD
10. Mathematics discoveries are doing more harm than good. (- Social)	SA	A	N	D	SD
11. I would rather agree with other people than do an experiment to find out for myself. (- Inquiry)	SA	A	N	D	SD
12. Mathematics lessons bore me. (- Enjoyment)	SA	A	N	D	SD
13. I dislike reading books about mathematics during my holidays. (- Leisure)	SA	A	N	D	SD
14. Working in a mathematics laboratory would be an interesting way to earn a living. (+ Career)	SA	A	N	D	SD
15. The government should spend more money on mathematical research. (+ Social)	SA	A	N	D	SD
16. I would prefer to do my own experiments than to find out information from a teacher. (+ Inquiry)	SA	A	N	D	SD
17. Mathematics is one of the most interesting school subjects. (+ Enjoyment)	SA	A	N	D	SD
18. A career in mathematics would be dull and boring. (- Career)	SA	A	N	D	SD
19. Mathematics lessons are a waste of time. (- Enjoyment)	SA	A	N	D	SD
20. Talking to friends about mathematics after school would be boring. (- Leisure)	SA	A	N	D	SD
21. I would like to teach mathematics when I leave school. (+ Career)	SA	A	N	D	SD
22. Mathematics helps to make life better. (+ Social)	SA	A	N	D	SD
23. I would rather solve a problem by doing an experiment than being told the answer. (+ Inquiry)	SA	A	N	D	SD
24. I really enjoy going to mathematics lessons. (+ Enjoyment)	SA	A	N	D	SD

25. Mathematics can help to make the world a better place in the future. (+ Social)	SA	A	N	D	SD
26. I would look forward to visiting a mathematics museum on the weekend. (+ Leisure)	SA	A	N	D	SD
27. It is better to be told mathematics facts than to find them out from experiments. (- Inquiry)	SA	A	N	D	SD
28. I would enjoy school more if there were no mathematics lessons. (- Enjoyment)	SA	A	N	D	SD

+ These items are scored 5, 4, 3, 2, and 1, respectively, for the responses SA, A, N, D and SD.
- These items are scored in the reverse manner.
Inquiry = Attitude to Mathematical Inquiry, Enjoyment = Enjoyment of Mathematics Lessons, Social = Social Implications of Mathematics, Leisure = Leisure Interests in Mathematics, Career = Career Interests in Mathematics.