

Science and Mathematics Education Centre

**The Influence of Classroom Environment on High School
Students' Mathematics Anxiety and Attitudes**

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Doctor of Philosophy
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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 other person except where due acknowledgment has been made.

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Abstract

The purpose of this research was to examine the possible associations between the perceived classroom environment of high school students, the level of mathematics anxiety that they possess, and their attitudes towards mathematics. This marks the first time that these three fields of research have been simultaneously combined.

Data were gathered from 745 high school mathematics students in 34 classes in high schools in the Southern California area using three instruments: the What is Happening In this Class?(WIHIC) learning environment survey created by Fraser, McRobbie, and Fisher (1996), an updated version of Plake and Parker's (1982) Revised Mathematics Anxiety Ratings Scale (RMARS), and a mathematics version of selected scales from Fraser's (1981) Test of Science-Related Attitudes (TOSRA). This revised attitude instrument was called the Test of Mathematics-Related Attitudes (TOMRA).

Using statistical methods, the three instruments were checked for internal consistency reliability, factor structure, and discriminant validity. The RMARS and WIHIC were both found to exhibit good reliability and factorial validity in mathematics classrooms in Southern California, while the TOMRA yielded two scales of the four *a priori* scales, Enjoyment of Mathematics Lessons and Normality of Mathematicians, which met reliability and factorial validity standards.

Within-class gender differences were analysed using paired *t*-tests combined with a modified Bonferroni procedure and effect sizes. Between-student gender difference were investigated using MANOVA. Simple correlation and multiple regression analyses were performed to identify possible associations between the learning environment and anxiety/attitudes scales. Qualitative data were collected from interviews and inductive analysis was performed in order to refute or corroborate the quantitative findings.

Significant within-class gender differences were found in four areas of the learning environment (Student Cohesiveness, Task Orientation, Cooperation, and Equity), but no gender differences in attitudes were found. All four learning environment areas were perceived in a more favourable light by females than by males. Individual gender differences were similar, with a significant difference also being found in Teacher Support, as well as both types of mathematics anxiety, namely, Learning Mathematics Anxiety and Mathematics Evaluation Anxiety.

In order to carefully identify the relationships between the classroom learning environment and mathematics anxiety, analyses were conducted for both factors of mathematics anxiety. While no association between the learning environment and Mathematics Evaluation Anxiety was found, there were significant associations between Learning Mathematics Anxiety and three areas of the learning environment: Student Cohesiveness, Task Orientation, and Investigation.

Significant associations between the Normality of Mathematicians attitude scale and the learning environment scales Equity and Involvement were identified, while three areas of the learning environment (Investigation, Task Orientation, and Cooperation) had a significant relationship with Enjoyment of Mathematics Lessons.

Qualitative data analyses confirmed relationships between anxiety, attitudes, and classroom learning environments. The data also suggest that the structure of the mathematical content is linked with the level of anxiety that high school students feel.

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Chapter 1

Introduction & Research Objectives

1.1 Statement of the Problem

Jennifer was a responsible 10th grade student when she was in my Algebra 2 class a few years ago. She was a dedicated student who never created any problems and faithfully did her homework, asked questions, and generally tried her best in class. One day, while I was teaching about the mathematical concept of asymptotes, she asked a question: "If those two lines never touch each other, are they parallel?" I carefully explained that, although they never touched each other, the two objects were still not considered parallel. Obviously, a previous instructor had explained the concept of parallel to her with that notion.

That was the last straw for Jennifer. She stood up out of her desk and yelled: "I've had it with all of you math teachers! You're all just a bunch of liars!" She proceeded to explain that mathematics teachers continually contradict each other. She said:

First, you tell me that I can't subtract bigger numbers from smaller ones. Then, someone tells me that there are negative numbers! Next I'm told you can't take the square root of a negative number, and then someone else says "Well, there are imaginary numbers". Now this! When does it all end?

What caused this reaction? What had been building up inside of her that finally had to be released? If she was willing to say these things, how many other students were feeling them? These questions have stuck with me in my teaching for many years, gnawing away at what I was doing in the classroom and whether it made a difference or not. Only later did I become aware of the

term 'mathematics anxiety', but I knew then I had run into something important and very real.

The research presented in this thesis is a result of working with students like Jennifer. Are there components of the classroom environment that either fuel or reduce mathematics anxiety in high school students? How are attitudes affected by what takes place in the typical high school mathematics classroom? These questions served as the foundation of the research that will be described in this thesis.

This initial chapter states the purpose and rationale for this research, its specific objectives, and the significance of a study in these areas. The second chapter reviews the relevant literature that pertains to my research in the areas of mathematics anxiety, attitudes towards mathematics, and the field of learning environments research.

Chapter 3 involves a discussion of the research methodology used to obtain and analyse the data, including a description of the sample used and the importance of combining qualitative and quantitative research methods. The fourth chapter summarises the findings of the various research analyses, while the final chapter discusses these findings and sheds light on future research opportunities within these fields, both individually and collectively.

1.2 Rationale for the Study

While much recent research has focused on the cognitive components of the mathematics classroom and its connection to achievement and success, little effort has been made to investigate the possible associations between the learning environment involved in a mathematics classroom and the affective areas of learning. Anxiety and attitudes towards mathematics are seen by many to be crucial areas which are essential for the improvement of mathematics education

(McLeod, 1992). If affective elements of the students' mathematical life are improved, then students' openness and ability in endeavors involving mathematics are more likely to reach their full potential.

This perceived lack of connection between mathematics education and research into learning environments has been identified as one of the priority issues for future analysis by L.D. English in the *Handbook of International Research in Mathematics Education* (2002). English states that stronger relationships between these two areas of research are important because it will enable and encourage students to reach to their full potential in mathematics and will permit research into learning environments in other disciplines to be incorporated into the mathematics classroom.

My study also attempted to look at the connection between the classroom learning environment and the attitudes that students hold towards mathematics and to their instructor. The normality of mathematicians, or in this case the mathematics instructor, has not been investigated in prior research. This marks the first time that all three research areas involving learning environment, mathematics anxiety, and attitudes towards mathematics have been brought together in the same study.

1.3 Research Objectives

My research was guided by four objectives:

1. To provide reliability and validity data for measures of mathematics anxiety, attitudes and classroom learning environment when used with high school students in Southern California.
2. To investigate gender differences in mathematics anxiety, attitudes and perceptions of learning environment using within-class and between-student comparisons.

3. To determine if there are associations between classroom learning environment dimensions and the level of mathematics anxiety and attitudes.
4. To explain why certain associations exist between mathematics anxiety and attitudes and learning environment by using qualitative research methods.

1.4 Significance of the Study

It is hoped that this study will have theoretical, methodological, and practical implications for the fields of mathematics education and classroom learning environments.

The theoretical contribution of this study is the bringing together of the three distinct research areas of mathematics anxiety, attitudes towards mathematics, and classroom learning environments. This conjoining of these fields within one study will hopefully set a precedent for further study.

Methodological implications of this study are focused on the instruments used and their reliability and validity in Southern California high school mathematics classrooms. The results from the factor analysis for the What is Happening In this Class? learning environment instrument, the Test of Mathematics-Related Attitudes, and the Revised Mathematics Anxiety Ratings Scale provide evidence for the appropriateness of these instruments for evaluating mathematics classrooms in Southern California, and whether they are valid and reliable measures of the areas that they propose to investigate.

The relationships that are found in my study are likely to have practical implications for the fields of learning environments, attitudes towards mathematics, and mathematics anxiety in high school mathematics classrooms. These findings will hopefully reinforce some beliefs that educators have regarding the important qualities of the learning environment and how they influence

students' anxiety and attitudes, and others will hopefully refute other widely-held notions that are not based on research.

The practical significance of this research involves the ability of students to study mathematics with less fear and anxiety and a more positive attitude in their classrooms. Guiding the classroom teacher in directing and focusing the environment in such a way that anxiety is diminished will be a major practical implication of this study.

Chapter 2

Literature Review

2.1 Introduction

Because my study investigated relationships between high school students' perceived level of mathematics anxiety, attitudes towards mathematics, and their perceptions of the classroom learning environment, a focused and detailed review of the literature in all three areas is provided in this chapter. Each of these research areas has a long and respected history. However, because their combination into a single study has not been undertaken prior to my research, it is important to familiarize ourselves with the research that has been performed in each area in order to build a framework upon which my study is based.

This chapter examines the literature surrounding the three main areas of focus for this study: the field of learning environments research (Section 2.2), the study of mathematics anxiety (Section 2.3), and research into attitudes towards mathematics (Section 2.4). I brought these fields of study together to get a unique perspective of high school mathematics classrooms in Southern California and the perceptions of the students who are located within them, as well as to find possible associations between the learning environment and the anxiety/attitude levels of students.

Through a review of the literature, it is my hope to achieve a clearer understanding of the areas involved in this research, as well as potential areas of difficulty or lack of consensus by those previously involved in these areas of research. It is also the intent of this review to seek commonalities between the

areas of research to build a foundation for the understanding associations between these areas.

2.2 Learning Environments Research

This section discusses the field of learning environments research, beginning with its history and foundations (Section 2.2.1). The formulation and background of a variety of instruments used to measure various components of learning environments is discussed next (Section 2.2.2), followed by an extensive look at the specific instrument used in this study (Section 2.2.3). The final part of this section reviews past areas of research found in the field of learning environments and the connections to my study (Section 2.2.4).

2.2.1 History and Foundations of Learning Environment Research

Fraser (1998a) defines the field of learning environment research as referring to “the social, psychological, and pedagogical contexts in which learning occurs and which affect student achievement and attitudes” (p. 3). This broad definition has enabled the field to encompass formal and informal learning situations across the spectrum of ages and instructional settings.

The origins of this field of study has its roots in the work of Herbert Walberg and Rudolf Moos and their individual attempts at studying participants’ perceptions of various learning situations (Moos, 1974, 1979; Walberg & Anderson, 1968). Moos (1974) previously had developed a scheme for classifying human environments into three dimensions: *relationship*, *personal development*, and *system maintenance and change*. These dimensions were the result of his research into a variety of environments in which people find themselves. These dimensions enable various components of an

environment to be classified and sorted. Moos then developed the Classroom Environment Scale (CES; Moos, 1979; Moos & Trickett, 1987) which further allowed researchers to study the specific learning environments related to schools.

Walberg's study of Harvard Project Physics led to the development of the Learning Environment Inventory (LEI), designed to assess the perceptions of students involved in the program. When brought together with Moos' work, and Lewin's earlier work (1936) involving field theory (the environment and its interaction with an individual's characteristics being determinants of human behavior), the complex study of learning environments began to take shape.

Another underlying theme in the study of learning environments came from Murray's (1938) work on the difference between outside observations and the perceptions of those directly involved within the specific environment being studied. Detached observation by an 'impartial' researcher had been the norm for many years in educational research. However, the approach of looking at the perceptions of both the students and teachers in a specific learning environment allowed the researcher to get a more personal perspective and to find nuances that might be missed by those not directly involved. While the perceptions of those involved with a specific environment can be skewed and biased, researchers also bring their own expectations and personal histories into situations and therefore cannot be totally impartial either.

Another distinction in the study of learning environments is the difference between the view of the individual student and the overall perceptions of an entire class. In that same work, Murray (1938) referred to the perceptions of the environment by participants as *beta press* (as opposed to the view of the outside observer which is known as *alpha press*). Stern, Stein,

and Bloom (1956) broadened this to distinguish between the views of a specific individual in an environment (*private* beta press) and those perceptions of the collective group as a whole (*consensual* beta press). This distinction leads to analysis of data from a variety of viewpoints and levels of statistical analysis, including the whole class or the individual student.

From this foundation, the field of classroom learning environments has grown and spread in its scope and depth, as demonstrated through the large number of articles and books regarding this field, and the international attention that this area has received (Fraser, 1998b, 2002; Fraser & Walberg, 1991). The recent development of an international journal dedicated to this field of study, *Learning Environments Research* (Fraser, 1998a), as well as books such as Goh and Khine's (2002) *Studies in Educational Learning Environments*, have helped to inform the worldwide educational community of the importance of this area of research.

2.2.2 *Learning Environment Instruments*

The most common method of investigating the learning environment has been through the use of survey instruments used to collect data on perceptions. This trend began with Walberg's LEI (Walberg & Anderson, 1968) and has flourished and expanded over the decades since. While many instruments have surfaced over the years, those that are most relevant to the issues researched in this study are overviewed in Table 2.1 and discussed in this section. Table 2.1 identifies a specific learning environment instrument, when it was developed, and how the scales in that instrument are classified according to Moos's dimensions of human environments. The past history of these scales is important for an understanding of how the field of learning environments has evolved over nearly 40 years of research.

As mentioned earlier, Walberg's LEI was used to study Harvard Project Physics in the late 1960s. Fifteen different learning environment dimensions were assessed via this instrument, but those most related to my research were the early introduction of scales measuring Cohesiveness and an early form of equity (Democracy). From the very beginning, the social relationships inherent in a classroom situation and the perceived fairness of the classroom were seen as important aspects of the learning environment. Fraser, Anderson, and Walberg (1982) analysed the LEI using internal consistency reliability and discriminant validity methods and found that the instrument is reliable and valid. Recently, Hirata and Sako (1998) used scales from the LEI in the Japanese language to determine a factor structure for the instrument as well.

In the 1970s, Rudolf Moos (1974) set out to investigate a variety of environments in which humans interact. While not all of these were formal educational situations, they did involve the perceptions of those participating in the environment being measured. From this work, the Classroom Environment Scale (CES) was formed (Moos & Trickett, 1987). This instrument contains scales measuring the relationship dimensions of Teacher Support and Involvement, as well as personal development areas like Task Orientation. These three areas are important qualities of the learning environment and still play a major role in the research being performed today.

Rentoul and Fraser's (1979) creation and publishing (Fraser, 1990) of the Individualised Classroom Environment Questionnaire (ICEQ) signaled the first attempt to measure the environment related to individualised and inquiry-based education. Due to the nature of these classrooms, one of the scales introduced was Investigation.

Table 2.1 – Scales from Eight Learning Environment Instruments for Secondary/Higher Education Settings Classified According to Moos's Scheme

Instrument	Date Developed & Authors	Items per Scale	Scales Classified According to Moos's Scheme		
			Relationship Dimensions	Personal Development Dimensions	System Maintenance and Change Dimensions
Learning Environment Inventory (LEI)	1968 Walberg & Anderson	7	Cohesiveness Friction Favouritism Cliquesness Satisfaction Apathy	Speed Difficulty Competitiveness	Diversity Formality Material Environment Goal Direction Disorganisations Democracy
Classroom Environment Scale (CES)	1974 Moos	10	Involvement Affiliation Teacher Support	Task Orientation Competition	Order and Organisation Rule Clarity Teacher Control Innovation
Individualised Classroom Environment Questionnaire (ICEQ)	1979 Rentoul & Fraser	10	Personalisation Participation	Independence Investigation	Differentiation
College and University Classroom Environment Inventory (CUCEI)	1986 Fraser & Treagust	10	Personalisation Involvement Student Cohesiveness Satisfaction	Task Orientation	Innovation Individualisation
Questionnaire on Teacher Interaction (QTI)	1990 Creton, Hermans, & Wubbels	8-10	Helpful/Friendly Understanding Dissatisfied Admonishing		Leadership Student Responsibility and Freedom Uncertain Strict
Science Laboratory Environment Inventory (SLEI)	1995 Fraser, Giddings & McRobbie	7	Student Cohesiveness	Open-Endedness Integration	Rule Clarity Material Environment
Constructivist Learning Environment Survey (CLES)	1995 Taylor, Dawson, & Fraser	7	Personal Relevance Uncertainty	Critical Voice Shared Control	Student Negotiation
What Is Happening In This Class? (WIHIC)	1996 Fraser, McRobbie & Fisher	8	Student Cohesiveness Teacher Support Involvement	Investigation Task Orientation Cooperation	Equity

Many of the ideas and motivations of the late 1970s have become fixed in the modern educational mindset, thereby making Investigation a regular and accepted part of classrooms today, as well as a regularly researched area of the learning environment. Asghar and Fraser (1995) used the ICEQ to investigate the relationship between students' classroom environment perceptions and their attitudes in Brunei.

In 1986, the College and University Classroom Environment Inventory (CUCEI) was created by Fraser and Treagust. Developed for small classrooms of less than 30 students, this instrument was created to examine the environments peculiar to higher education. Again, the scales included the personal development dimension of Task Orientation, as well as the relationship dimensions of Involvement and Student Cohesiveness. While designed for higher education situations, there are many similarities between small university seminars and the classrooms in American high schools. The number of students involved and the teaching styles are quite similar. These dimensions are therefore appropriate for investigating the high school classrooms as well.

Yarrow, Millwater, and Fraser (1997) recently used the CUCEI as part of a study designed to improve the classroom learning environments of preservice primary teachers both in the university setting and eventually in the students' own classrooms. Joiner, Malone, and Haines (2002) used the CUCEI to assess the inclusive nature of reformed calculus classes in university settings and found that, even with reform changes, students viewed the actual classroom environment less favourably than their preferred environment.

The Questionnaire on Teacher Interaction (QTI; Creton, Hermans, & Wubbels, 1990; Wubbels & Levy, 1993) was designed to research the interaction between students and teachers. The questionnaire, which

originated in the Netherlands, relies heavily on the theoretical model of proximity (cooperation – opposition) and influence (dominance – submission) and measures the student's perceptions of eight areas of behaviour and relationship (Leary, 1957). While no specific scales of this questionnaire are related to this research, the belief that the interaction between student and teacher is an important component to the educational environment has generally been accepted and lies at the heart of other scales such as Teacher Support.

The QTI is still used extensively to determine relationships between teachers and students (Fisher & Rickards, 1998; Fisher, Rickards, & Newby, 2001; Lee & Fraser, 2001). Past research using the QTI has found that students view their 'ideal' teachers as strong, friendly leaders who are more understanding and less uncertain, dissatisfied and admonishing than the average teacher (Fisher, Rickards, & Fraser, 1996). Previous research with the QTI has also focused on outcome-environment associations for outcomes such as achievement and interest/attitudes towards computers (Soerjaningsih et al., 2001) as well as the attitudes of science students (Quek et al., 2001).

The Science Laboratory Environment Inventory (SLEI) was created by Fraser, Giddings, and McRobbie (1995). This instrument was one of the first designed for a specific learning situation, namely, secondary and university school science laboratory classes in this case. While this specialized environment is a part of a larger educational system, there are unique qualities and characteristics that are associated specifically with a laboratory class. The SLEI includes scales that measure components of the environment such as Student Cohesiveness and a form of investigation named Open-Endedness.

The SLEI has been used to measure the environment of science laboratory classes in Singapore (Quek et al., 2001; Wong & Fraser, 1994), Tasmania (Fisher et al., 1998), and Korea (Kim & Kim, 1995, 1996; Lee &

Fraser, 2002). It has also been used in chemistry, biology, and physics laboratory classes as well (Fisher et al., 1998; Henderson & Fisher, 1998). It also has motivated a number of other specialized instruments to take shape. Some of these include the Distance and Open Learning Environment Scale (DOLES; Jegede, Fisher, & Fraser, 1995) designed for use among those studying by distance education, and Maor and Fraser's (1996) instrument used to evaluate computer-assisted learning.

At roughly the same time that the SLEI was constructed, an instrument for assessing the classroom environment's constructivist orientation was formed. The Constructivist Learning Environment Survey (CLES; Taylor, Dawson, & Fraser, 1995; Taylor & Fraser, 1991; Taylor, Fraser, & Fisher, 1997) was originated to aid teachers and researchers as they determine whether a classroom is consistent with constructivist theory. The constructivist theory of learning states that individuals learn based on their own previously-constructed knowledge, active negotiation within the classroom, and consensus building. This instrument attempts to identify the level of constructivist learning that is perceived by either the instructor or students in a specific situation.

The CLES has been used to measure active learning environments in several countries and academic settings. Nix, Fraser, and Ledbetter (2003) used the CLES in the United States to study science classrooms, while Sebela, Aldridge, and Fraser (2003) promoted teacher action research in South Africa using this instrument. The CLES has also been translated into Korean for use in high school science classrooms (Lee & Fraser, 2001) and into Chinese for a cross-national study between Taiwan and Australia (Aldridge, Fraser, Taylor, & Chen, 2000). These studies have allowed this instrument to gain considerable favor among researchers looking at the classroom from a constructivist's viewpoint.

While the seven scales of the CLES are not directly relevant to my research, the foundation of the constructivist view permeates the education world and is fundamental in many of the aspects that modern classroom learning environments instruments attempt to measure. The active negotiation sought in a constructivist view cannot happen without teacher support and equity, and consensus building must include areas of investigation and involvement for it to be accepted and meaningful to the students.

The final instrument that is listed in Table 2.1 is the What Is Happening In this Class? (WIHIC) survey. Because this survey was used in my research, the literature relevant to the history, formulation, and use of the WIHIC follows in the next section (Section 2.2.3).

2.2.3 *What Is Happening In this Class? (WIHIC) Survey*

One of the latest tools for investigating classroom learning environments is the What Is Happening In this Class? (WIHIC) survey designed by Fraser, McRobbie, and Fisher in 1996. This instrument has quickly become widely used to measure the perceived psychosocial learning environments of students worldwide. Already it has been shown to be valid and useful for measuring various learning environments in Western Australia (Zandvliet & Straker, 2001), Canada (Raaflaub & Fraser, 2002; Zandvliet & Straker, 2001), Brunei Darussalam (Khine & Fisher, 2001, 2002; Riah & Fraser, 1998), Indonesia (Margianti, Fraser, & Aldridge, 2002; Soerjaningsih, Fraser & Aldridge, 2001), Singapore (Chua, Wong, & Chen, 2001; Fraser & Chionh, 2000), Malaysia (Zandvliet & Man, 2003), Taiwan (Aldridge, Fraser, & Huang, 1999), South Africa (Ntuli, Aldridge, & Fraser, 2003), Korea (Kim, Fisher, & Fraser, 2000), and in the United States (Martin-Dunlop & Fraser, 2004; Moss & Fraser, 2001; Pickett & Fraser, 2004).

The WIHIC was originally comprised of eight scales, but has been revised to include seven scales that measure across the three dimensions of Moos (1974). Student Cohesiveness, Teachers Support, and Involvement measure the environment from a relationship perspective, both in a student-to-student and a student-to-teacher direction. Investigation, Task Orientation, and Cooperation assess elements of the personal development dimension, focusing on components of the classroom environment that are directly related to students' motivation and unique learning styles. Equity is used to measure elements from the system maintenance and change dimension related to the perceived fairness of the classroom structure and instructor. It is evident that many of the dimensions and scales from previous instruments influenced the formation and construction of the WIHIC.

The WIHIC is comprised of eight questions for each of the seven scales being measured. Using a five-point Likert rating scale (*Almost Never* to *Almost Always*), a composite score for each of the scales can be produced for use in data analysis. While both a 'preferred' and an 'actual' form of the instrument have been created, my study used only the 'actual' form in order to identify the present perceptions of the subjects involved regarding the learning environment within which they are presently located.

Confirmatory factor analysis of the WIHIC has recently been conducted to verify the validity and integrity of the instrument (Dorman, 2003). Dorman used a variety of analyses including reliability, exploratory factor analysis, and confirmatory factor analysis to study the WIHIC. Using a cross-national sample from the United Kingdom, Canada, and Australia ($N=3980$), Dorman reported that the WIHIC is a valid measure of classroom environment and has a wide range of applications, especially in Western countries.

The WIHIC has been used to measure a wide variety of classroom situations and settings as well. Researchers have used it to measure situations from early primary (Allen & Fraser, 2002) to professional development programs for those already teaching (Pickett & Fraser, 2002). It has been used to investigate geography and mathematics classes (Fraser & Chionh, 2000), biology classes (Moss & Fraser, 2001), chemistry classes (Riah & Fraser, 1998), and classes with an information technology emphasis (Khoo & Fraser, 1998; Raafuab & Fraser, 2002; Zandvliet & Fraser, 1998; Zandvliet & Man, 2003; Zandvliet & Straker, 2001)

This instrument has been used to investigate relationships between the classroom environment and other educational issues. For example, these include academic efficacy (Dorman, 2001), information technology (Zandvliet & Man, 2003; Zandvliet & Straker, 2001), interventions for at-risk student (Gray, Aldridge, & Fraser, 2003), and the influence of the cultural background of the teacher (Khine & Fisher, 2001, 2002). All of these studies have attempted to identify relationships and associations between the educational issue and the learning environment scales.

One of the applications for which the WIHIC has been used with increasing frequency is investigating within-class gender differences (Fraser & Chionh, 2000; Khine & Fisher, 2001, 2002; Khoo & Fraser, 1998; Kim, Fisher, & Fraser, 2000; Margianti, Fraser, & Aldridge, 2002; Riah & Fraser, 1998). This analysis enables the researcher to determine possible differences between males and females in their perceptions of the learning environment from within the same classroom situation. A typical pattern in past research is that females tend to hold more favourable perceptions than do males in the same classroom.

Also, the WIHIC has been used in a number of cross-national studies designed to compare learning environments in different countries (Adolphe,

Fraser, & Aldridge, 2003; Aldridge et al., 2000; Aldridge, Fraser, & Huang, 1999; She & Fisher, 2000; Zandvliet, 2002). This is extremely interesting because this research not only illuminates the differences in the educational environments of different nations, but also their great similarities. Cross-national studies also take into account that the varieties of cultures and languages can affect the learning environment. These additional factors can then be used in the analysis to determine if they influence the learning environment or the achievement of students.

Relevant to my study is past research that used the WIHIC to determine possible associations between classroom learning environment factors and attitudes towards educational areas, specifically science (Adolphe, Fraser, & Aldridge, 2003; Wong & Fraser, 1996). The relationship between the perceived learning environment and students' attitudes towards a specific subject area can give great insight into the mindset and demeanor of the students towards these subjects. While this has been done frequently with regards to science, it has not been used often within the area of mathematics.

It can be readily seen that the WIHIC instrument seems to bring together scales and ideas from some of the very best learning environment tools of the past two decades. These scales, combined with new dimensions of contemporary educational relevance, have yielded a simple yet powerful tool for the classroom environment researcher. Its strong factor structure and reliability in a variety of global classroom settings, and in a variety of languages, offers the researcher a tool that can assess aspects of learning environments quickly and effectively. For these reasons, the WIHIC was selected for my study as the primary means by which to evaluate components of the learning environment in order to determine possible associations with the students' level of mathematics anxiety and their attitudes towards mathematics.

2.2.4 *Areas of Past Research in Learning Environments*

The many past uses of the WIHIC begin to show the great variety and scope of the field of learning environments research. Studies in this field, using many of the instruments listed previously, have attempted to connect with areas of educational theory and practice. By reviewing these previous areas of research, we can get a clearer picture of the scope of the field and become aware of certain areas that might not have used this research approach in the past.

Fraser (1998c) identifies 12 distinct areas of research that involve classroom learning environment instruments. These areas, listed in Table 2.2, involve three areas that are highly relevant for my study. My study attempted to identify associations between the learning environment and students' outcomes, especially affective outcomes. This is also connected to the area of past research involving school psychology, especially as mathematics anxiety is related to psychology. Finally, the combined use of qualitative and quantitative methods is one of the 12 areas that Fraser lists as well. This area will be discussed at length in Chapter 3.

Many researchers (Fraser, 1994, 1998b; Fraser & Walberg, 1991; Goh & Khine, 2002) have used learning environment instruments on a global scale to analyse and investigate the environment and its influence on the achievement and attitudes of students. While many of these outcomes are cognitive in nature, the role of attitudes towards a specific subject area is included in this realm.

Table 2.2 Areas of Past Research in the Field of Learning Environments and Their Emphases

Research Area	Main Emphasis of Research
Associations between Student Outcomes and Environment	Investigation of associations between perceptions of psychosocial characteristics of a classroom and students' cognitive and affective learning outcomes
Evaluations of Educational Innovations	Process criteria used in the evaluation of educational criteria are obtained via classroom learning environment instruments
Student-Teacher Differences	Investigation of perceived differences between the students and teacher in a classroom situation. Differences could be between actual or preferred environments
Person-Environment Fit	Research into whether student achievement depends on the similarity between preferred and actual classroom environment
Teacher Improvement	Instruments provide feedback information for use in five-step procedure for reflecting upon, discussing, and attempting to improve classroom environment
Combining Research Methods	Research involving the use of both quantitative and qualitative methods in the same study in order to identify salient features of the environment studied
School Psychology	Research instruments can be used to identify areas of classroom life and differences that impact the mental and emotional welfare of students
Links between Environments	Attempts to identify connections and influences of multiple environments involved in the education process, both in and out of the formal school
Cross-national Studies	Unique abilities to investigate the similarities and differences between the educational environments of various countries, as well as to question the practices and beliefs of a given country
Transitions between Grade Levels	Research on the effect of students moving from one level of education to another, such as from primary to junior high school
Teacher Education	Opportunities to include the topic of learning environments in programs for the preparation and training of future educators
Teacher Assessment	Dimensions of learning environments can yield insight into present teaching methods and focus, as well as possible effectiveness from the student perspective

Researchers have also studied the difference between the 'preferred' and 'actual' environment that students and teachers encounter (Fisher & Fraser, 1983) in order to determine if what a student desires in a classroom environment is what they perceive themselves to be receiving. My study used only the 'actual' form of the instrument.

The review of the literature involving mathematics anxiety (Section 2.3) suggests that much of the foundations of that field are directly connected to the field of psychology. The psychological dynamics of the classroom, both positive and negative attributes, have formed a consistent area of study within the field of learning environments. While there has not been a lot of research in this area, Burden and Fraser (1993) did use the discrepancies between students' perceptions of the actual and preferred environment to guide improvements in classrooms.

Recently, there have been some questions raised regarding conceptually separating the individual from the environment and whether this can actually take place. Roth (2000) states that a person and the perceived learning environment are inseparable and therefore asserts that the learning environment instruments should not stand alone, but that other means by which to investigate uniqueness and differences for each individual involved should be used. Roth states that, in his view, learning environment surveys are best used as identifiers of issues and precursors to other forms of investigation. This agrees with the use of multiple approaches to research, including combining quantitative and qualitative methods, as Tobin and Fraser (1998) have suggested.

2.3 Mathematics Anxiety

A crucial component of the learning environment is the emotional and affective feelings that students bring into the classroom regarding a specific subject area. While feelings of joy and enjoyment are certainly helpful and welcomed in the classroom, feelings of fear and dread seem to be a part of some classrooms where some subjects are taught, especially in the area of mathematics.

The study of mathematics anxiety has its foundation in the general study of the psychology of anxiety, especially in the work of C.D. Spielberger. Spielberger (1972) states that anxiety is a “condition characterized by feelings of tension and apprehension” (p. 24). This tension is divided into two types of anxiety: *state* and *trait*. ‘State’ anxiety is an emotional condition that varies in intensity and fluctuates over time, while ‘trait’ anxiety is a feeling that is at the core of an individual who perceives a variety of situations as dangerous or threatening. Mathematics anxiety would be a form of state-anxiety.

Rachman (1998) provides four theories of anxiety to help to define it even further. Two of the four theories, psychoanalytic and biological, could account for some of the anxiety perceived in a classroom, but neither would probably be the leading cause of mathematics anxiety. The other two theories, cognitive and learning, seem to be more in line with the common thoughts regarding mathematics anxiety. The fears associated with the learning process that generate avoidance behaviors (learning theory) or the reactions that come from the lack of knowledge regarding an event (cognitive theory) are directly connected to the anxiety due to mathematics or mathematics classes.

Others have found factors that impair cognitive abilities from an affective perspective. Ellis and associates (1993) state that worry and

emotionality have negative impacts on cognitive ability. Here worry is defined as “intruding thoughts that reflect self-concern, doubt, or other negative affect” and emotionality as the “heightened arousal state of an individual”(p. 86). This is most likely a result of the work of Wigfield and Meece (1988) in which worry and emotionality were assessed among Grade 6 - 12 students. Later, these two researchers joined with Eccles in a study which drew on self-efficacy theories to identify predictors of mathematics anxiety (Meece, Wigfield, & Eccles, 1990). They found that students’ current performance expectancies have the strongest direct effect on anxiety, but also that perceptions of importance of mathematics also play a role in student anxiety levels.

A recent feeling among researchers is that mathematics anxiety has become a catch-all for any negative feeling regarding mathematics and therefore the term has lost some of its value due to this. While definitions seem to span the spectrum of possibilities (McLeod, 1992), Buckley and Ribordy’s (1982) definition clarifies what most people think of when they hear the term *mathematics anxiety*:

Mathematics anxiety is an inconceivable dread of mathematics that can interfere with manipulating numbers and solving mathematical problems within a variety of everyday life and academic situation. (p. 1)

One area investigated by researchers is the connection between mathematics anxiety and test anxiety and the possible overlap that exists between these two types of anxiety. Kazelskis and associates (2000) have pointed out that *mathematics anxiety* and *test anxiety* can be different constructs, but that mathematics anxiety needs to be delineated and defined further. This connection between mathematics anxiety and test anxiety is a good example of the ‘cognitive’ theory of anxiety as set forth by Rachman (1998) and previously mentioned.

Likewise, Zettle and Raines (2000) investigated the relationship between trait, test, and mathematics anxiety. While finding that the relationship between mathematics anxiety and test anxiety was stronger than that between mathematics anxiety and trait anxiety, they also concluded that maintaining a distinction between mathematics anxiety and test anxiety was appropriate. The reason for this is that, while test anxiety can be a part of the overall picture of mathematics anxiety, it is not the only determining factor and therefore is only a part of what we call mathematics anxiety.

The study of mathematics anxiety has progressed since the creation of the Mathematics Anxiety Ratings Scale (MARS) (Richardson & Suinn, 1972; Suinn, Edie, Nicoletti, & Spinelli, 1972) in the early 1970s. This survey allows researchers to probe the level of mathematics anxiety that a person feels, both in and out of the classroom environment. This initial research tool spawned many others, including revised versions of the MARS (Alexander & Martray, 1989; Plake & Parker, 1982), the Mathematics Anxiety Questionnaire (Wigfield & Meece, 1988), and the Fennema-Sherman Mathematics Attitude Scale (Fennema & Sherman, 1976). Each of these instruments, including the original MARS, was designed with multiple dimensions of mathematics anxiety in mind.

All of these instruments are able to identify the level of mathematics anxiety by measuring the feelings and emotions associated with mathematics situations. The causes of mathematics anxiety, however, are not that easily discernable according to Martinez and Martinez (1996):

Mathematics anxiety is complex. It rarely follows a straightforward, single-cause/single-effect, linear progression. It has multiple causes and multiple effects... (p. 6)

Martinez and Martinez go on to state that identifying that someone is mathematics anxious only defines the symptom, not the cause of the

anxiousness. Because of this, it is difficult to pinpoint the various components surrounding a student's mathematics anxiety, some of which can be internal and some of which can be environmental. Furner and Duffy (2002) state that mathematics anxiety can be influenced by any of the following: the school system, gender, socioeconomic status, and parental history and prejudices.

This can be seen through the various dimensions of mathematics anxiety that have been measured through the various instruments listed previously. Kazelskis (1988) said that a unidimensional approach to mathematics anxiety cannot provide an adequate understanding, but that careful selection of an instrument is needed as each measures various attributes and dimensions of this phenomena. For example, the MARS and its shorter versions seem to measure what Kazelskis calls 'mathematical test anxiety', 'numerical anxiety', and 'mathematics course anxiety'.

My study focused on the two dimensions of mathematics anxiety as defined by Plake and Parker's Revised MARS (1982). Learning Mathematics Anxiety and Mathematics Evaluation Anxiety are components of mathematics anxiety assessed by the RMARS, and are related to two of Kazelskis's types of anxiety as listed previously. Because of this conceptual distinction, it is important methodologically to generate a separate score for each distinct area of anxiety when relating anxiety to the learning environment dimensions as assessed by the WIHIC.

Plake and Parker's RMARS has been used sparingly since its inception, but has been shown to yield results that are just as reliable as the original MARS (Capraro, Capraro, & Henson, 2001; Hannafin, 1985; Kazelskis, 1988; Plake & Parker, 1982), but in a shorter instrument (24 questions versus the original 96). Lester and Hand (1989) used the RMARS to identify anxiety among students in a college-level statistics course. Likewise, Williamson and Mattiske (2002) used the revised version in a similar situation. Blum and

Staats (1999) used Plake and Parker's RMARS to identify mathematics anxiety relationships within a computer classroom setting. These studies, coupled with the factor analysis provided by researchers, show us that the RMARS is reliable and an appropriate instrument for use in my study (Kazelskis, 1988; Plake & Parker, 1982).

One area that has been agreed upon by many researchers as a key element in mathematics anxiety is the role of the teacher in the classroom (Martinez & Martinez, 1996; Tobias, 1978; Zaslavsky, 1994). Most of the attention on instructors is through the negative ways in which they contribute to their students' mathematics anxiety (Furner & Duffy, 2002; Jackson & Leffingwell, 1999; Oberlin, 1982). Ho and associates (2000) go on to say that, while some tension is important for learning situations, instructors should avoid environments that involve negative situations such as nervousness and dread. The role of the teacher, especially through positive support and the feelings of equity that they portray, are components that this research will also investigate.

Grouws and Cramer (1989) also looked at the role of teachers within the framework of problem solving. They found that the classrooms of effective teachers of problem solving skills were very supportive environments, not only of the students as individuals, but of the enjoyment of problem solving and the enthusiasm of the students. This support was crucial as students were asked to strive towards success and open themselves to new and difficult problem-solving techniques.

Another major focal point for mathematics anxiety research has been the question of gender differences with regard to the level or reasons for mathematics anxiety. Many researchers (Campbell & Evans, 1997; Hembree, 1990; Levine, 1995; Meece, 1981) have focused on this issue and have come to some agreement regarding the differences between male and female levels of

mathematics anxiety. The research points to differences in mathematics anxiety between male and female students, but identifying a single cause or reason has been difficult. Most researchers who identify gender differences state that females have higher anxiety than males (Hembree, 1990; Meece, 1981).

Recently, Sherman and Wither (2003) have investigated whether mathematics anxiety causes a deterioration of mathematics achievement, whether poor mathematics achievement caused mathematics anxiety, or some third factor that caused both. Through their research, they determined that researchers can reject the belief that mathematics anxiety causes a deterioration of achievement. However, they could not reject the other two hypothesis based on their findings. This encourages the continued discussion if the classroom environment is connected to that possible third factor mentioned.

Mathematics anxiety, while not universally defined, is prevalent in students in classrooms today, especially in the secondary setting. Because of the literature that precedes this study, we can view mathematics anxiety as a multidimensional construct and analyse at least two of the components of this anxiety in this study, namely, Learning Mathematics Anxiety and Mathematics Evaluation Anxiety. Also, there is evidence that there are factors present in the learning environment that can be determinants or influences of mathematics anxiety as well. This study attempted to identify those factors. Further discussion of how anxiety was assessed in my study follows in Chapter 3.

2.4 Attitudes towards Mathematics

While anxiety is one emotional element that has been identified as important in the mathematics classroom, other affective elements have also

been identified and researched as well. These elements have traditionally been included under the term 'attitude' and have been studied by researchers for quite some time. The difficulty with analysing this literature is that this term refers to a variety of different things and is not at all uniform in definition or purpose.

Hannula (2002) attempts to identify four aspects of attitude which could help in the prospect of defining what is being referred to when this term is used:

1. emotions aroused in a situation
2. emotions associated with a stimulus
3. expected consequences
4. relationship of a situation to personal values. (p. 26)

While these four areas are themselves broadly defined, at least they give a framework with which to categorise constructs involved with this area of study. All of these aspects are involved in some form or another when the term 'attitudes towards mathematics' is used in the literature.

McLeod (1992) approaches the topic of attitudes from a different perspective. Instead of using the term 'attitude', McLeod prefers the term 'affect' to describe the broad notion of all emotions, beliefs, and feelings regarding mathematics. Anxiety, confidence, and frustration are then seen as subsets of this 'affective' area.

McLeod divides the affective domain in mathematics education into three categories: beliefs, emotions, and attitudes. He defines 'beliefs' as those things related to the long-term study of mathematics. These 'beliefs' include cognitive feelings related to the teaching of mathematics, opinions of self and the teacher's role, and the social context in which mathematics is taught. This

is in contrast to the second category, called 'emotions', which are fleeting and changing and not necessarily cognitive at all.

McLeod's third category is called 'attitudes'. This area focuses on the likes and dislikes of students, the enjoyment that they feel during lessons, and the preferences that they have during mathematics instruction. This area of preferences is closely related to the 'preferred' environment found in the learning environment research listed previously.

Dungan and Thurlow (1989) conducted a meta-analysis of the literature on attitudes towards mathematics and found that research had identified associations between student attitudes to mathematics and teacher qualities, student personality or social factors, gender, parental influences, peer influences and intelligence (p. 11). In a fairly short period of time, the factors thought to influence these attitudes have gone from being primarily internal, or classroom related, to more external and focused on social norms. This has now continued into analysing the cultural influence of attitudes by researching a variety of ethnic backgrounds and their specific outlooks on mathematics as a culture (Butty, 2001; Chouinard, Vezeau, Bouffard, & Jenkins, 1999).

Attitudes towards mathematics have been studied with regards to achievement and gender differences for quite some time (Aksu, 1991; Fennema & Sherman, 1976; Ma, 1997; Ma & Kishor, 1997). Research in this area has turned towards age differences, as well as exploring where gender-related attitudes change over time (Vanayan, White, Yuen, & Teper, 1997). While few gender differences in attitudes towards mathematics have been found among early elementary students (Suydam, 1984), research has found that, as students age, noticeable differences in their attitudes can begin to appear. Some researchers have found decreases in belief in the usefulness of mathematics as all students get older (Mason, 2003) while others have found

that deteriorations in attitudes are more of a problem for males than for females (Chouinard, Vezeau, Bouffard, & Jenkins,1999).

Leder (1992) states that the study of gender differences actually highlights the role that the environment plays in learning. Both the personal and situational environments are seen as having impacts on this gender difference with regards to attitude and learning. This ties in extremely well with research on classroom environments also. The perceived environment of the entire class and that of the individual are commonly accepted as important areas of study in most research into associations between learning environment and learning.

Ma (2003) recently found that possible declines in attitude are dependent on a student's capabilities and the degree of curriculum acceleration in which the student was involved. This study again attempted to connect the level of achievement of a student with his/her ability. Ma found that as a student's capabilities in mathematics grows, the attitude towards mathematics improves.

Some researchers are skeptical that the attitudes of students towards mathematics typically decrease over time. Deeds and associates (1999) found that students actually were fairly positive towards mathematics and that educators have reason to be optimistic. But even this good bit of news for those involved with mathematics education was coupled with the finding that college-aged students find very little connection between mathematics, technology, and citizenship.

Two of the areas that have been investigated in prior research regarding attitudes towards science are the level of enjoyment regarding science lessons and the normality of scientists in the eyes of students. Fraser (1981) first incorporated these areas into his attitudinal instrument, the Test of

Science Related Attitudes (TOSRA). These two areas were seen as two possible keys to determine the nature of students' attitudes towards science and whether it was more positively or negatively directed.

However, throughout past research in mathematics education, enjoyment of mathematics lessons has been investigated to a limited extent, and students' view of the normality of the mathematicians has not been used previously in research. These two components of the affective element in mathematics instruction, while previously overlooked, seem to be ready to be highly relevant. These fit well into Hannula's (2002) fourth aspect of attitude, that relating to personal value, and would help to define more extensively the role that attitude plays in the learning of mathematics.

Early in the study of attitudes towards mathematics, surveys were formed that attempt to identify salient factors related to this area. One of the first, and probably the most well known, was the Fennema-Sherman Attitude Scale (1976). Originally, it was used to study gender differences in attitudes using nine scales: attitude towards success in mathematics; mathematics as male domain; mother, father, and teacher scales; confidence in learning mathematics; mathematics anxiety; effective motivation in mathematics; and perceived usefulness of mathematics. These scales were employed in an attempt to paint a wide picture of possible factors involved in a student's attitude. Through further research (Melcancon, Thompson, & Becnel, 1994; Mulhern & Rae, 1998), the survey was shown to be reliable and valid, even in a shortened form.

Another survey designed for this purpose is Sandman's (1980) Mathematics Attitude Inventory. This survey measures 'attitude' through the use of six scales: the value of mathematics, self-concept in mathematics, anxiety towards mathematics, enjoyment of mathematics, motivation in mathematics, and perceptions of mathematics teachers. The major difference

between this and the Fennema-Sherman instrument is that it incorporates the notion of 'enjoyment' as a part of the attitude, and not just motivation, success, and personal interaction.

At the same time, the question of attitudes of students towards science topics and classrooms was beginning to take shape and was quantified through the construction of the TOSRA (Fraser, 1981). This instrument is designed to measure attitudes towards science among secondary school students. Originally, seven items were developed for each scale based on a classification scheme designed by Klopfer (1971). These items attempted to delineate meanings associated with the term 'attitude towards science'. These included areas of favourable attitudes towards science and scientists, acceptance of scientific inquiry as a way of thought, adoption of science attitudes, enjoyment of science lessons, and development of interests in science, science-related activities, or possible science-related careers.

The TOSRA has been used to measure a variety of areas of attitudes towards science (Adolphe, Fraser, & Aldridge, 2003; Aldridge, Fraser, & Huang, 1999; Waldrip & Fisher, 2001). Some of the uses have been tied to the relationship between student attitudes and student achievement (White & Richardson, 1993), connections between gender and attitudes (Joyce & Farenga, 1999; Smist & Owen, 1994), and the training of inservice science teachers (Brown, 1996; Lott, 2002).

The importance of these instruments in quantifying and investigating attitudes towards mathematics and sciences is enormous. Without some kind of means of identifying and comparing the strengths of certain attitudes, this area of research would remain a word game of defining and redefining criteria. Through these instruments, the capability now exists to compare the attitudes in one place or of one person with those in another situation or environment.

2.5 Conclusion

These three fields of study, namely, research into learning environments, mathematics anxiety studies, and attitudes towards mathematics are time-tested and relevant. While some of these areas have experienced a muddling of the terminology, the concepts that they study have important qualities for students today, especially because they are readily seen and felt in the classrooms of today's students.

We have seen in this chapter that each of the fields of study involved in my research are founded upon a rich research history and have been implemented in a variety of studies in the present. The field of learning environments, originating in the separate works of Walberg and Moos, has expanded and grown in scope and depth. A variety of instruments have been developed to measure dimensions of the learning environment, including one of the newest and most promising tools, the What Is Happening In this Class? (WIHIC) survey. Measuring seven psychosocial factors of the learning environment, the WIHIC has been successfully implemented in research worldwide.

The field of mathematics anxiety has also experienced both growth and frustration in the past years. Originating in the psychological theories of anxiety by C.D. Spielberger, many studies have taken place which attempted to identify reasons for mathematics anxiety's existence. These studies, however, have not been able to identify a single reason for mathematics anxiety. But, because of the vast array of contributing factors, there has been some misunderstanding and vagueness in defining what is included in this area. Instruments, such as the Revised Mathematics Anxiety Ratings Scale (RMARS) from Plake and Parker, have attempted to identify factors related to this condition and assess them from each student.

The study of attitudes towards mathematics has mainly focused on the area of gender differences and the potential decline of attitudes as students grow older. These studies have connected attitudes towards mathematics with the level of achievement in mathematics in many cases. While mathematics education has focused most of its research on the association between attitudes and achievement, science education has brought in other perspectives of the role of teachers and the level of enjoyment in science lessons to see if they influence the attitudes towards science as well. The Test of Science-Related Attitudes (TOSRA), as well as many other instruments, have attempted to quantify these influences of attitudes. These areas may also influence the area of mathematics education, and are implemented here via a revised version of the TOSRA focused on the area of mathematics.

Separately, each of these three areas of study is powerful and significant. But it is the bringing together of these three areas in this study that sheds new light on the interaction and associations between the learning environment, the mathematics anxiety that students feel, and the student attitudes towards mathematics that will enable us to see more clearly what is taking place in mathematics classrooms.

Chapter 3

Research Methodology

3.1 Introduction

The method by which research is conducted is the 'lifeblood' of the study, allowing others to see the inner structure of the project and give meaning and credibility to the results. This chapter attempts to clearly describe the research methods of my study and thereby reinforce its credibility.

My study attempted to identify associations and relationships between the perceived learning environment of high school students in mathematics classrooms located in Southern California and the level of mathematics anxiety a student feels and the attitudes that these students hold towards mathematics and mathematics instructors. My study used three instruments which were to be validated for use with this sample. The data collected from these instruments, combined with qualitative data from interviews, served as the foundation upon which these relationships would be investigated.

The importance of combining quantitative and qualitative methods, especially with respect to research in the field of learning environments, is discussed in Section 3.2. Information regarding the data sources and sample are discussed (Section 3.3), with a detailed review of the quantitative data-gathering instruments and their modifications following immediately thereafter (Section 3.4).

Section 3.5 includes the quantitative data methods while the qualitative data methods are discussed in Section 3.6. The chapter concludes with an

overview of potential biases and limitations in my study (Section 3.7) and some concluding remarks in Section 3.8.

3.2 Combining Quantitative and Qualitative Research Methods

One of the more powerful trends in research today is the combining of qualitative and quantitative research methods to obtain a clearer picture of the data and those subjects involved in the sample (Fraser & Tobin, 1991; Tobin & Fraser, 1998). This approach allows a 'triangulation of data', which is fundamental in obtaining validity in research (McKnight et al., 2000). This 'triangulation of data' includes the inspection and re-inspection of concepts from a variety of viewpoints. These methods are also designed to determine whether the various data agree with each other or whether there are differences or nuances involved depending on which type of data is considered.

The role of the researcher has been described as one of a 'bricoleur' or a jack of all trades or a quilt maker (Denzin & Lincoln, 2000). This gives the image of a person who takes items from a number of places and formulates a montage to describe the situation. Modern educational research techniques encourage the use of a wide range of data types and analysis methods in order to more clearly understand the dynamics and impact of the situation being studied.

Denzin and Lincoln go on to identify differences between qualitative and quantitative research methods as well. They list five distinctions between the two types of methods in order to further identify the value of each in research, especially when research involves human subjects.

The first difference that Denzin and Lincoln describe is founded in a philosophical outlook on what is being researched. Positivism is the belief that there is a reality to be captured and that this can be studied and documented, while post-positivism says that this reality can never be fully understood and only

approximated in some form. This post-positivistic view usually relies on multiple methods of research in order to capture as much as possible of the reality that is present. With the number of individuals involved in educational research, along with their perceptions and idiosyncrasies, a post-positivistic view is certainly called upon in studying educational environments.

A second difference is that qualitative methods accept a postmodern approach of investigation. Research is attempting to tell the story of what is taking place in a certain situation with a certain sample. Qualitative methods are just a different method of telling that same story and, when connected to quantitative methods, of adding depth and insight. As research attempts to tell us what is taking place in any situation, it is imperative that the combining of these two methods be used to tell that story more fully.

Thirdly, qualitative methods help to capture the individual's point of view, not just the collective story as told by quantitative methods. This enables us to get closer to what an individual might perceive and how it compares to the entirety of the group. While the perceptions of the class as a collective can give researchers insight into the dynamics and social structure of a group, it is the individual's story that adds the flavor to the final understanding of what is really taking place in that group.

Next, Denzin and Lincoln (2000) identify that qualitative methods can yield rich descriptions and give a color and vibrancy to the research. If we see the researcher as 'bricoleur', as stated earlier, then it is vital that the data be presented to reflect those nuances of the human condition and to use personal descriptions to highlight what the quantitative data is pointing towards.

Finally, the use of qualitative methods can illuminate the constraints of everyday life and bring those variables into the picture. Especially when working with human subjects, this element of the social aspects of human culture is

interwoven with the emotions, attitudes, and approaches that are undertaken, especially in educational endeavors.

While Denzin and Lincoln's five differences help us to see the need for combining qualitative and quantitative methods in a study, there is an underlying sense that quantitative methods can be seen as dull or lifeless. This does not seem to be the case to me. The quantitative data analysis yields for the researcher a perspective and focus that can enable the qualitative data to have meaning and not just be an abstract or isolated fact. It is the power of using the two approaches together which enables a fuller picture to be 'painted' by the researcher.

McLeod (1992, p. 582) states: "When the research methodology becomes more flexible and more studies use multiple research methods, including interviews rather than just questionnaires, we can expect research on attitudes to make new contributions to the field of mathematics education." It seems that we have reached this point in the world of research. Tobin and Fraser (1998) have clearly stated that this is a preferred way to conduct research into learning environments, and it seems to provide my study with further means to analyse mathematics anxiety and other affective elements in mathematics education.

Tobin and Fraser (1998, p. 627) state that this combining of qualitative and quantitative research methods allows the researcher to describe the learning environment through "multiple windows". This enables a study to focus on a variety of issues and reach a wider audience. In my study's case, there are issues for the classroom teacher as well as the learning environment researcher that need to be considered.

This method of combining research methods has become the standard involving research into learning environments. Templeton and Johnson (1998) used quantitative and interpretive methods to investigate school safety. Likewise, Aldridge, Fraser, and Huang (1999) used multiple research methods, including

interviews, to investigate environments between Taiwanese and Australian schools. These, plus many other studies (Allen & Fraser, 2002; Dorman, Fraser, & McRobbie, 1994; Maor & Fraser, 1996), are just a sample of studies that reflect this change towards a multiple-methods approach.

While my study did combine qualitative and quantitative methods in investigating associations between the perceived learning environment of students and their perceived anxiety and attitudes, the qualitative methods were less comprehensive than the quantitative. The qualitative methods were used in a confirmatory manner, thereby enhancing the potential validity of the quantitative findings.

3.3 Data Sources and Sample

Data for my study were collected from high-school students (Grades 9 through 12) from four schools in the Southern California area. These co-educational high schools, both public and parochial, have diverse cultural and socioeconomic settings. Table 3.1 shows the racial and ethnic breakdown of the students in the high schools used in my study. This enables us to see the diverse nature of the students involved.

Table 3.1 --- Demographics of Sample High Schools

School	Location	Enrollment	Racial/Ethnic Percentages				
			Hispanic or Latino	African-American	Asian - American	White	Other
Foothill HS	Tustin, CA	2473	32.4%	1.9%	8.1%	55.6%	2.0%
Loara HS	Anaheim, CA	2087	51.2%	2.8%	12.4%	29.9%	3.7%
Lutheran HS	Orange, CA	997	5.9%	0.8%	3.5%	87.0%	2.8%
Tustin HS	Tustin, CA	2109	44.4%	6.3%	13.7%	30.5%	5.1%

Southern California is diverse and multicultural, and these schools reflect the makeup of the surrounding communities. With the high percentage of students in the sample schools coming from White/Caucasian or Latino/Hispanic cultures, the sample is consistent with many other high schools in the area.

From these four schools, a sample of 745 students from 34 classes was used in the research. While many more students completed some of the questionnaires used, these 745 students were the only individuals to complete all of the three instruments used in my study (see Section 3.4). In order to investigate associations between the perceived learning environment and students' mathematics anxiety and attitudes, it was important that all three instruments were completed by those included in the study.

Selected mathematics classrooms across all grade levels from each school were used in the research. This enabled a balanced view of the issues across grade level, age, and level of classes. A breakdown of the grade levels is found in Figure 3.1.

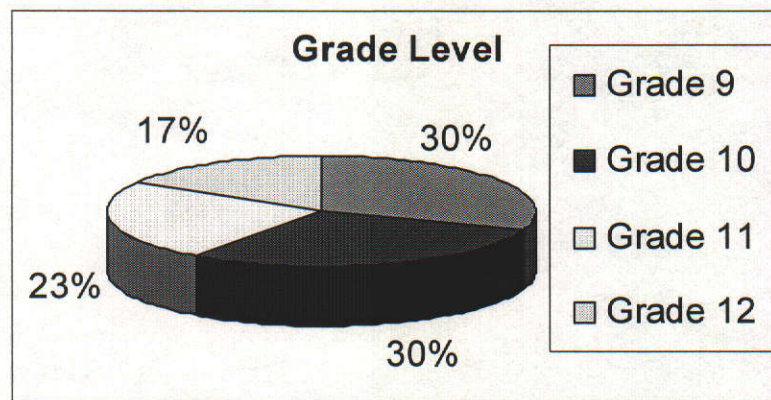


Figure 3.1 Percentage of the Sample from Each Grade Level

The sample also reflected a balanced view of the population in terms of gender as well. Just over half of the sample identified themselves as male (52.3%), while 47.7% were female. This even division of the sample should decrease any possible gender biases in the data.

The sample for this study provides a good representation of the population of the Southern California area, except that it could have been a little more representative of the African-American population. The diversity of culture, gender, and socioeconomic characteristics is likely to allow my study to yield a broad view of the perceptions of learning environments and the anxiety and attitudes regarding mathematics in Southern California grade 9 through 12 students.

3.4 Instruments and Modifications

Three instruments were used to gather data for the quantitative analyses of this study. These instruments measured student perceptions of the learning environment, their attitudes towards mathematics and mathematicians, and the students' level of mathematics anxiety stemming from the learning of mathematics and the evaluation of their learning. Surveys were distributed and completion was supervised via the classroom teachers within a five-week period of time. Because the questionnaires have a strong history of use, especially in the United States, it was felt that the classroom teachers could appropriately collect the data without compromise or bias.

This section gives a more detailed account of each of the instruments, as well as any modifications that took place for my study. Section 3.4.1 looks at the learning environment questionnaire known as the What Is Happening In this Class? (WIHIC; Fraser, McRobbie, & Fisher, 1996). The next section describes the attitude instrument called the Test of Mathematics-Related Attitudes (TOMRA). This survey is a mathematics-specific modification of the Test of Science-Related Attitudes (TOSRA; Fraser, 1981). The final section (Section 3.4.3) discusses the instrument used to measure mathematics anxiety known as the Revised Mathematics Anxiety Ratings Scale (RMARS; Plake & Parker, 1982).

3.4.1 *What Is Happening In this Class? (WIHIC) Survey*

The What Is Happening In this Class? (WIHIC) learning environment questionnaire was developed by Fraser, McRobbie, and Fisher in 1996 to measure the perceptions of students in seven psychosocial areas: *Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, and Equity*. This instrument was used in my study without any modifications or changes and can be found in Appendix A. It uses a five-point frequency response scale ranging from *Almost Never* to *Almost Always*. There are eight questions for each scale in the WIHIC.

As stated in Chapter 2, the WIHIC has a rich background and was developed using the best scales from many previous learning environment instruments. The end result is a questionnaire that can assess the learning environment from a number of different perspectives. The WIHIC consists of two versions which measure either the preferred classroom environment of the student or the actual environment. This tool was appropriate for my study because of the breadth of areas that are included, as well as its ability to measure students' perceptions of the actual classroom in which they are located.

The WIHIC instrument has shown itself to be a valid and reliable tool across countries and cultures. Dorman (2003) has recently published a review of the questionnaire and has shown that it is useful for measuring the perceived learning environment in many countries and cultures. Using almost 4000 students from the United Kingdom, Canada, and Australia, Dorman demonstrated that WIHIC possesses a high level of integrity by using reliability, exploratory factor analysis, and confirmatory factor analysis.

While its use in mathematics classrooms has been limited (Fraser & Chionh, 2000; Raaflaub & Fraser, 2002; Spinner & Fraser (in press)), it has become

widely accepted by many others investigating learning environments, especially when searching for relationships with attitudes or gender differences (Adolphe, Fraser, & Aldridge, 2003; Fraser & Chionh, 2000; Khine & Fisher, 2001, 2002; Khoo & Fraser, 1998). These studies have allowed researchers to determine possible differences between males and females and how they perceive the learning environment. This is extremely relevant to my study as the question of the possible differences in the way the learning environment impacts anxiety between the genders is a main focus of my research.

The WIHIC has also been used a number of times to determine the possible associations between attitudes related to science and the perceived learning environment (Adolphe, Fraser, & Aldridge, 2003; Kim, Fisher, & Fraser, 2000; Riah & Fraser, 1998). These studies pursued research questions similar to the one that I ask regarding the relationship between mathematics attitudes and the learning environment. Because the WIHIC has already been used in this type of situation, it is appropriate to extend in to the area of mathematics as well.

Because of the solid factor structure, reliability, and acceptance in the study of learning environments by other researchers, the WIHIC was seen as the best choice for my study for measuring student perceptions of their classroom environment. Also, because this instrument was used with a new sample (high school mathematics in Southern California), I conducted factor and reliability analyses in order to confirm that the WIHIC is suitable for use with this population in the future.

3.4.2 *Test of Mathematics-Related Attitudes (TOMRA)*

A mathematics-specific version of Fraser's (1981) Test of Science-Related Attitudes (TOSRA) was used to measure attitudes related to the learning of mathematics and towards mathematicians in general. The TOSRA is composed of seven scales measuring student attitudes towards science and science-related areas. The original TOSRA has 10 questions for each scale.

The modified instrument used in my study is referred to as the Test of Mathematics-Related Attitudes (TOMRA) and measures student attitudes in four areas: *Normality of Mathematicians*, *Attitudes towards Mathematics Inquiry*, *Adoption of Mathematics Attitudes*, and *Enjoyment of Mathematics Lessons*. The structure, design, and format of the TOMRA questions were kept identical to the TOSRA but, wherever the term 'science' appeared, it was replaced with the term 'mathematics'. The four scales retained from the original TOSRA were deemed by me and my thesis supervisor to be the most relevant to my study learning environment and mathematics anxiety. Consultation with the author of TOSRA confirmed that the removal of these three scales would be unproblematic.

A five point Likert-scale is used in this instrument, with responses ranging from *Strongly Agree* to *Strongly Disagree*. Some questions are positively phrased, while others are negatively worded. This required that some scoring be reversed for the data analyses. A copy of the TOMRA and the scoring table can be found in Appendix B.

Few previous studies have used the TOMRA in mathematics education research. However, the TOSRA has had a rich history of use and it is still being used to measure attitudes towards science today (Adolphe, Fraser, & Aldridge, 2003; Aldridge, Fraser, & Huang, 1999; Waldrip & Fisher, 2001). The possible relationships between gender and attitude have been studied with the TOSRA (Joyce & Farenga, 1999; Smist & Owen, 1994). The relationship between gender and attitudes towards mathematics is at the heart of my study as well.

Because of this history, and the relatively close connection between mathematics and science content, it was felt that a mathematics version of the TOSRA would be appropriate for investigating students' attitudes towards mathematics and mathematicians. The TOMRA serves my study well by investigating the attitudes of students towards mathematics and mathematical-

related areas in order to determine possible associations with the classroom learning environment.

3.4.3 Revised Mathematics Anxiety Ratings Scale (RMARS)

An updated version of Plake & Parker's (1982) Revised Mathematics Anxiety Ratings Scale (RMARS) was used to measure student levels of anxiety in two areas: *Learning Mathematics Anxiety* and *Mathematics Evaluation Anxiety*. The Mathematics Anxiety Ratings Scale (MARS) was originally created by Richardson and Suinn in 1972 and consisted of 96 questions in these two areas. Later, it was revised by Plake and Parker into 24 questions of which 16 are related to the Learning Mathematics Anxiety scale. Factor analysis has been performed on the RMARS multiple times (Capraro, Capraro, & Henson, 2001; Hannafin, 1985; Kazelskis, 1988; Plake & Parker, 1982). Each time it has shown a consistent two-factor structure and high reliability.

After nearly 20 years of use, I determined that the previous items in the RMARS needed to be adapted to more current methods of mathematics instruction and terminology. This resulted in roughly half of the questions needing modification in some way. Table 3.2 shows the changes from the original RMARS used in my study. The RMARS also uses a five-point frequency response scale ranging from *Not At All Anxious* to *Very Much Anxious*. A complete copy of the updated RMARS can be found in Appendix C.

This instrument has been used to measure mathematics anxiety levels involving students in statistics class (Lester & Hand, 1989; Williamson & Mattiske, 2002) as well computer classes (Blum & Staats, 1999). The original instrument, as well as the revised version, has been viewed as the primary tool for measuring mathematics anxiety since its inception. The two-factor mathematics anxiety definition has helped to clarify the multifaceted aspects of mathematics anxiety

Table 3.2 --- Modifications to RMARS

Item Wording		
Item #	RMARS (Plake & Parker, 1982)	Modifications to RMARS
1	Watching a teacher work an algebraic equation on the blackboard.	Watching a teacher work an algebra equation on the blackboard.
2	Buying a mathematics textbook.	Being given a mathematics textbook on the first day of class
3	Being given a homework assignment of many difficult problems which is due the next class meeting.	Being given a homework assignment of difficult problems which is due the next class meeting.
4	Thinking about an upcoming mathematics test on the day before.	No change
5	Solving a square root problem.	No change
6	Reading and interpreting graphs or charts.	No change
7	Signing up for a course in statistics.	Getting your schedule and seeing a mathematics class on it.
8	Listening to another student explain a math formula.	No change
9	Walking into a math class.	No change
10	Looking through the pages of a mathematics book.	No change
11	Starting a new chapter in a mathematics book.	No change
12	Walking on campus and thinking about a mathematics course.	Walking onto campus and thinking about a mathematics course.
13	Picking up a mathematics textbook to begin working on a homework assignment.	No change
14	Taking an examination (quiz) in a mathematics course.	No change
15	Reading the word "Statistics".	Reading a word associated with mathematics, such as "geometry" or "average".
16	Working on an abstract mathematical problem such as: "If x =outstanding bills, and y =total income, calculate how much you have left for recreational expenditures".	Working on an abstract mathematical word problem.
17	Reading a formula in chemistry.	Reading a formula in a science class.
18	Taking an examination (final) in a mathematics class.	No change
19	Getting ready to study for a mathematics test.	No change
20	Being given a "pop" quiz in a mathematics class.	Being given an unannounced quiz in a mathematics class.
21	Waiting to get a mathematics test returned on which you expected to do well.	No change
22	Listening to a lecture in a mathematics class.	No change
23	Having to use tables in the back of the mathematics book.	Having to use a calculator or table to solve a problem.
24	Being told how to interpret probability statements.	Being told how to solve an algebra equation or write a geometry proof.

and has allowed a deeper connection between other areas of study and mathematics anxiety.

Because of its history and reliability, the RMARS was chosen to measure the mathematics anxiety levels of the students involved in the sample. The shorter version of the RMARS, as opposed to the original and longer MARS, was used to elicit the best responses of the students while remembering their maturity level and attention span. After extensive consultation with my thesis supervisor, it became clear that there were no important differences between the revised version of the RMARS and the original. Therefore, no major compromises or problems arose because of the modifications I made to RMARS.

3.5 Data Analyses

All data collected from the three instruments was entered into a spreadsheet and rechecked for accuracy. This process took approximately two months to complete. Three research assistants helped in the data entry and double checked each other's entries in order to ensure accuracy. Student identification numbers, gender, grade-level, and class identification markers were also kept for each student who had completed all three instruments fully.

The quantitative data analyses were focused on three objectives. First, validity and reliability of the three questionnaires were obtained in order to check their suitability for my study and their appropriateness for measuring the desired areas (Section 3.5.1). Once the scales from the questionnaires were shown to be valid and reliable, gender differences were investigated for each scale using both within-class and individual levels of analysis (Section 3.5.2). Finally, associations and relationships between the learning environment scales and the anxiety/attitude scales were computed using simple correlation and multiple regression techniques (Section 3.5.3).

3.5.1 *Validity and Reliability of Questionnaires*

Each of the three instruments was assessed for internal structure, reliability, and validity. The internal structure of each questionnaire was determined using a factor analysis method, while reliability was assessed through the Cronbach alpha coefficient. Discriminant validity for each instrument was determined using the mean correlation of a scale with the other scales in that instrument as a convenient index. Analysis of variance (ANOVA) was also used to check whether each scale would differentiate between classrooms.

Factor analysis was carried out by using the SPSS (2001) statistical analysis program which implements a principal component analysis involving scree plots, eigenvalues, and a varimax rotation method with Kaiser normalisation. This procedure is designed to isolate the potential factors in a questionnaire and to determine the internal structure of an instrument. This method has been previously used for factor analysis by learning environment and mathematics anxiety researchers (Fraser, 1981; Fraser, McRobbie, & Fisher, 1996; Plake & Parker, 1982).

The varimax rotation method with Kaiser normalization is a statistical method used to separate the factor loadings into mutually exclusive areas. This process separates each factor and uses linear algebra to distinguish these factors as much as possible. Factor loadings for individual items were calculated to determine whether they were above 0.40 with their own, and only their own, scale. Scree plots and eigenvalues are secondary ways of seeing graphically and numerically that these factors are indeed unique and separate from the others. The total percentage of variance from each scale was calculated to determine the strength of each individual scale the collective strength of the instrument.

Internal consistency reliability was determined through the use of the Cronbach alpha value (McKnight et al., 2000). The formula for Cronbach's alpha coefficient is:

$$\alpha = \frac{N\bar{p}}{1 + \bar{p}(N - 1)}$$

where N is equal to the number of total items being tested, and $\bar{\rho}$ is the average of the correlation between each pair of items. The Cronbach alpha has an upper bound of 1 so that, as the alpha coefficient is closer to that value, the higher is the reliability of the scale. This coefficient was calculated using both the individual student and the class mean as the unit of analysis.

It has also been shown that the Cronbach alpha serves as the lowest bound for any estimate of reliability of N items (Novick & Lewis, 1967). Recently, some have questioned whether it is the best method to determine reliability or if other techniques should be considered (Vehkalahti, 2000). The strong tradition of using the Cronbach alpha, especially in the field of learning environments research, suggests that there is a strong precedent to use it in my research, especially so that the results might be compared to previous research findings.

The discriminant validity of each scale was measured by using the mean correlation of a scale with the other scales in that instrument as a convenient index. This value is the average Pearson correlation value between a scale with each of the other scales. When the mean correlation coefficient is smaller, then the probability that each of the scales is measuring concepts different from the other scales is greater.

Also, for the learning environment instrument, the η^2 statistic from ANOVA was used to determine whether each scale is capable of differentiating between the perceptions of students in different classrooms. This is an important statistic as the ability to differentiate between classrooms can signal that the instrument is sensitive to the difference between individual instructors or classrooms and how they can influence a classroom environment. Class membership was used for the main effect in the ANOVA. The η^2 statistic, which is the ratio of the sum of squares between with the total sum of squares, indicates the proportion of variance in the scale accounted for by class membership.

3.5.2 Identifying Gender Differences

After the factor and item analyses showed that the instruments were reliable and valid, the data from that instrument were analysed through a variety of techniques and methods. Initially, gender differences were explored using within-class gender means and individual student scores as the units of analysis.

Within-class gender means are the averages for a factor separating by class and gender. The purpose of using this unit of analysis is to reduce the possible confounding that can arise when males and females are represented in different proportions in different classes. By using paired *t*-tests, it was determined if there are significant differences between the genders on the factors being analysed.

For *t*-testing involving multiple comparisons, a modified Bonferroni method was used to reduce the possibility of finding significance due to strictly random chances (Holland & Copenhaver, 1988; Jaccard & Wan, 1996). The modified Bonferroni procedure ranks the probabilities obtained from the significance testing and multiplies the most significant result by the number of tests being performed. If this value is smaller than the desired alpha, the result is considered significant. The next most significant result is multiplied by one less than the number of tests and compared to alpha again. This process continues with successive probabilities and remaining number of tests until a nonsignificant result is obtained.

While the modified Bonferroni procedure reduces the chance of Type I error (accepting a nonsignificant result), it does increase the possibility of Type II error occurring (rejecting a significant result). Due to number of tests being performed in my study and because multiple research methods were used, it was determined that this procedure was appropriate for use in conjunction with paired *t*-tests with multiple comparisons.

Also used was effect size, which enables differences to be evaluated without sample size playing a role (Cohen, 1988). Effect size is the magnitude of a difference between two samples. Cohen defines the effect size as the difference between the two means divided by a pooled standard deviation. This standardizes the difference between the means in terms of the number of standard deviations. Coupled with traditional significance testing, effect size allows researchers to analyse results with multiple methods (Wainer & Robinson, 2003).

Gender differences were explored using the individual as the unit of analysis by performing a Multivariable Analysis of Variance (MANOVA). This technique involved simultaneous analysis of variance tests being performed on all learning environment, attitude, and anxiety scales to determine significant differences. Also associated with this was a test to determine possible interaction between gender and grade level. After multivariate tests revealed significant gender differences overall ascending to Wilks' lambda criterion, the corresponding ANOVA was interpreted for each individual dependant variable.

3.5.3 *Determining Associations between Learning Environment and Attitude/Anxiety Scales*

Simple correlation and multiple regression analyses were used to determine possible associations between the learning environment factors and the factors of mathematics anxiety and attitudes. Correlation analysis involving simple Pearson product-moment correlations was used to explore possible bivariate associations between each of the learning environment factors with each anxiety and attitude scale.

In order to determine the joint relationship between the set of learning environment scales and the outcomes of anxiety and attitudes, the set of learning environment scales was used as independent variables in multiple regression analyses, with anxiety and attitudinal scales serving as dependent variables.

Simple linear regression was used as there were no expectations that non-linear representations existed in the relationships.

The resulting linear equation serves as a mathematical model of the influence of the learning environment areas upon the variance of the anxiety/attitude factor when all the learning environment scales are mutually controlled. This model is useful in determining which areas of the learning environment have a significant and independent impact on the level of students' anxiety or attitude towards mathematics when all other environment scales are mutually controlled. These results also served as a basis by which the interview questions were constructed and asked.

These quantitative methods are illustrated further in Chapter 4, along with the findings of each statistical test. While these represent standard procedures in quantitative data analysis, they also serve my study by setting the direction of the interviews and aligning the results with other research in the fields of learning environments, mathematics anxiety, and attitudes towards mathematics.

3.6 Qualitative Methods

A standardized open-ended interview using extreme case sampling was implemented to clarify the findings from the quantitative data collection (Patton, 1990). This allowed possible confirmation or denial of the quantitative results by questioning students regarding their perceived classroom environment and its effect on their anxiety level and attitudes towards mathematics. Students with extremely high or low levels of mathematics anxiety were selected to be involved in the interview portion of my research.

Each of the interviews was recorded, with the participant's permission, and then transcribed verbatim. Using Patton's (1990) inductive analysis approach, common themes or philosophies were investigated from the transcripts

and individual perspectives were considered. The results were compared with the findings from the quantitative data and similarities and differences were identified. The inductive analysis approach is similar to factor analysis in that major themes were identified from the responses of the students. Quotations act as the main unit of analysis in this process. After individual quotations are extracted from the responses, a first level of grouping takes place to find preliminary common themes. A second, and sometimes third, grouping then takes place to find the major points of emphasis from the responses given.

This is representative of what Silverman (2000) calls the 'narrative approach' for qualitative data gathering. This approach attempts to access various stories and views by which people describe the world around them, or the reality that a person perceives. Silverman states that this method "opens up culturally rich ways that interviewers and interviewees generate plausible accounts of the world" (p. 823).

This 'narrative approach' is opposed to what Silverman calls the 'realist approach' to interview data. In this approach, the researcher is attempting to ensure a completely accurate depiction of what the realities are. In effect, the researcher is attempting to determine the one reality, and thereby check the accuracy of this depiction through other observations.

It was assumed in my study that the learning environment and its influence on the mathematics anxiety and attitudes of high school students could not be considered as a single reality, but that each person brought perceptions of various attributes and nuances of what was taking place and how the affective elements of the class were influenced by the environment. Because of this philosophy, the interview questions were focused on the results of the qualitative data analysis findings and used as confirmation of those results.

Also influencing the interview portion of my study was the research objective of determining possible gender differences with regards to the learning environment influence. Fontana and Frey (2000) point out that social and gender issues cannot be ignored while conducting interviewing, but that there are many factors that make up a complex framework by which interviewing takes place. These elements which influence a person's perceptions necessarily appear in their responses, and therefore should help in determining the questioning from the researcher as well.

3.7 Limitations and Biases of the Study

Research, especially when it involves human subjects, is susceptible to limitations, biases, and invalidity. Cohen, Manion, and Morrison (2001) identify four stages when biases and invalidity can invade a research project: research design, data gathering, data analysis, and data reporting. These authors also include a variety of techniques and strategies which enable a researcher to minimize invalidity and biases. This section looks at each stage of research and address how my study attempted to minimize biases and invalidity.

Cohen and associates (2001) list the first stage of research when biases and invalidity can occur as the design stage. Here they state that threats to validity can be minimized by looking at a number of issues prior to starting the research. Choosing an appropriate time frame, making sure there are adequate resources available and using appropriate instruments are three of the suggestions which can reduce biases later. These areas have been appropriately covered and do not contribute to any biases or limitations in my study. The collection of data for my study took place over a period of five months and were not rushed in any way. Adequate resources, such as answer sheets, writing utensils, and designated time blocks, were also taken into consideration. I also believe that I have shown that the instruments used for my study are appropriate for the age of the students involved.

However, there are two potential areas in the design stage which could be questioned and which could give rise to potential biases or invalidity. First, the use of an appropriate sample for my study could contribute to any potential issues. The main issue could be the relatively small sample size ($N=745$) which was implemented for use with correlational and multiple regression analyses. While the total student population of the four schools is nearly 7000 students, access was not granted to all classrooms and a number of individuals did not complete all three instruments. While the sample is fairly small, it is large enough to carry out the data analyses without invalidating the results or findings.

One other area listed by Cohen and associates (2001) for potential biases in the design stage involves avoiding a biased choice of researcher to carry out the study. As for myself, I am certain that my time spent in high school mathematics classrooms creates an amount of bias and some perceptions which cannot be removed. Every effort has been made on my part to avoid personalising the research project or placing my own expectations on the data.

While the individual instructors might have some hidden need to manipulate the data or data collection in order to make their classroom environments seem more positive, steps were taken in order to minimize this potential and to ensure that the data collected are a good representation of the students' actual perceptions. The instructors were informed that this research was not aimed at an individual's classroom, but at a composite picture of high school mathematics classrooms in Southern California. They were also informed that no data or analysis would be shared based on an individual's classroom and that only I would know from which classroom any data came via the classroom coding system.

The second stage of potential bias in research as mentioned by Cohen and associates (2001) was in the data-gathering stage. Areas of concern for invalidity in this stage involve reactivity effects, standardizing procedures for data

gathering, and tailoring the instruments to the concentration span of those responding. Reactivity effects are when those responding behave or act differently because they are being observed or interviewed. In my study, every effort was made to ensure that the interview process was conducted with a minimum of stress and that the students felt comfortable about answering freely (see Appendix G for interview questions and protocol).

The procedure for distributing the questionnaires and collecting the responses was left to the individual teachers, with some guidance and suggestions shared in a letter sent prior to data collection (see Appendix F) as well as during visits from myself to the classroom teachers. While this could have led to a variety of methods of distribution (three consecutive days, once a week, etc...), I do not believe that it compromised the integrity of the data collected. Informal communication with the individual teachers after the questionnaires were completed seems to suggest that students completed the questionnaires with the same attitude and attention.

Due to the difference of attention spans in adolescent students, it was felt that, in order to receive honest responses, the instruments would need to be carefully chosen and possibly modified. This is why the Revised Mathematics Ratings Scale (RMARS, 24 questions) was chosen to measure the mathematics anxiety factors instead of the larger and more detailed Mathematics Anxiety Ratings Scale (MARS, 96 questions). The 40-question Test of Mathematics-Related Attitudes (TOMRA) was also seen as having appropriate length for measuring attitudes towards mathematics among high school students. While the What Is Happening In This Class? (WIHIC) learning environment instrument has a total of 56 questions, there are only 8 questions for each of the seven scales, thereby making it seem less daunting and overbearing to the students.

The third stage of potential bias in research is the area of data analysis. Cohen and colleagues (2001) seem to point to two major areas of concern which

could increase the potential of bias being incorporated into a study. The first area is what could be called 'poor data management'. This would include research indiscretions such as poor coding of qualitative data, selective use of data, inappropriate statistical treatments and methods, and simple data entry errors. Careful selection of criteria for use of data was incorporated prior to my study's beginning and all methods are in agreement with previous research involving learning environments or mathematics anxiety.

The second area from Cohen and associates in this stage of data analysis could be labeled 'poor data interpretation'. Potential invalidity can occur when researchers exclude validity testing of responses, make subjective interpretive statements based on the data, equate correlations and causes, and include Type I or Type II errors. Validity testing for all questionnaires was performed in my study, and care was taken to not equate correlations with causes or to make subjective statements beyond what the data provides.

The issue of balancing Type I and Type II error is always at a tension within research. While trying to reduce the Type I error, a researcher automatically increases the potential for Type II error. Data analysis methods such as the Bonferroni procedure attempt to minimize Type I error and have been discussed previously. This correction was implemented in my study in order to find a balance between the potential errors.

The final stage of data reporting is listed by Cohen and associates (2001) as the last place for bias and limitations to enter into research. The major errors associated with this stage include misrepresenting the data and ensuring that the research questions are answered fully. Consideration has been given to these areas in my research. All results communicated in Chapter 4 are related to the research questions. Also, care has been taken to ensure that the data are represented in a clear and concise manner.

While bias and some degree of invalidity is present in all research, the awareness of what can cause research to slip into these problems can lead to a preventive approach aimed at reducing the level of bias present. This has been the goal of my study. Though some areas still allow questions to be raised, there is good reason to be reasonably confident that the results of my study are valid and appropriate.

3.8 Conclusion

This study is founded on the union of qualitative and quantitative methods in order to 'triangulate' the data regarding the influence of learning environments on the attitude and anxiety towards mathematics of high school students. By using a sample that is diverse and balanced, this study gives a broad and wide-sweeping view of these areas and their impact on the learning that is taking place. The sample for my study, while relatively small for the kind of data analysis used, is reflective of the gender, socioeconomic, and racial structure of high schools in the Southern California area.

Four levels of analyses were performed in my study. Initially, factor, reliability, and discriminant validity analyses were performed in order to determine the appropriateness of the instrument data for the sample used in my study. Secondly, gender differences were investigated for all scales from the learning environment, attitude towards mathematics, and mathematics anxiety areas. Both within-class means and individual student scores were used in the analyses of gender differences. Next, associations and potential relationships were determined between the learning environment factors and the attitude/anxiety areas by using simple correlation and multiple regression analyses. Finally, interviews were conducted and the data were analysed using an inductive method of determining common themes in the data. This served to corroborate or refute the findings obtained from the quantitative data.

Many of the potential areas of bias and invalidity have been addressed prior to the beginning of my study through the design structure. A few areas of concern are still present, mostly due to sample size, but not enough to jeopardise the results of this study or invalidate the data.

Chapter 4

Data Analyses and Results

4.1 Introduction

My study used three instruments to determine possible associations between the perceived learning environment in high school classrooms, the level of mathematics anxiety that students feel, and their attitudes towards mathematics. 745 students in 34 classes from four high schools in Southern California formed the sample for this study.

The learning environment was assessed through the use of the What Is Happening In this Class? (WIHIC) learning environment survey which measures the students' perceived environment in seven areas: Student Cohesiveness, Teacher Support, Investigation, Involvement, Task Orientation, Cooperation, and Equity (Fraser, McRobbie, & Fisher, 1996). Attitudes towards mathematics were quantified using four scales from the Test of Mathematics Related Attitudes (TOMRA): Normality of Mathematicians, Adoption of Mathematics Attitudes, Attitudes towards Mathematics Inquiry, and Enjoyment of Mathematics Lessons (Fraser, 1981). Two aspects of mathematics anxiety, namely Learning Mathematics Anxiety and Mathematics Evaluation Anxiety, were measured via the Revised Mathematics Anxiety Ratings Scale (RMARS; Plake & Parker, 1982). Qualitative data were obtained through interviews from a subsample of the students completing the instruments described above.

This chapter reports the analyses of the data undertaken to answer each of the research questions for this study. Factor, reliability, and validity analyses for each learning environment, anxiety, and attitude instrument are reported first (Section 4.2). Second, within-class and whole-sample gender differences for each

of the scales are discussed (Section 4.3), followed by a report of associations between the learning environment scales and anxiety or attitude factors using simple correlation and multiple regression analyses (Section 4.4). Finally, results of the qualitative data collection are shared in an attempt to corroborate or refute the findings from the quantitative data-collection methods (Section 4.5).

4.2 Reliability and Validity of the Instruments

My study's first aim was to provide reliability and validity data for instruments assessing learning environment, mathematics anxiety, and attitudes towards mathematics when used with high school students in Southern California. These measures of reliability and validity attempt to identify the level of confidence researchers can have in the results obtained from using the instruments. The extent to which a survey instrument yields consistent data and measures distinct factors gives credibility to the results based on data obtained using the instrument.

One method that is commonly used to determine or check the internal structure of an instrument is factor analysis. Through numerical calculations, factor analysis identifies the areas of an instrument that have common themes and are answered in a similar fashion by those participating in the study. These common areas, known as factors, allow researchers to reduce the number of variables or items contained in an instrument to focus more closely on components of the area to be studied. If the factor analysis results for an instrument with one sample are consistent with previous analysis from a different sample, then that gives credibility to that instrument.

Data collected from administering the questionnaires were analysed using a separate principal component factor analysis involving a Kaiser varimax rotation for the WIHIC, RMARS, and TOMRA. This method has the ability to identify factors by maximizing the variance and then isolating the factors for easy

identification. Scree plots, eigenvalues, and the total percentage of variance from the factor analysis were used to determine factor strength as well.

Reliability and validity analyses were carried out to explore the properties of the scales and the items involved in measuring them. Internal consistency was measured using Cronbach's alpha coefficient. Discriminant validity, or the extent that each scale is unique and independent, was measured using the mean correlation of a scale with the other scales in that instrument. In addition, for the classroom learning environment questionnaire, the eta² statistic from an analysis of variance (ANOVA) was used as a measure of the ability of each scale to differentiate between the perceptions of students in different classrooms.

Even though the WIHIC and RMARS instruments have a long and well-documented record that supports their factorial structure and validity, and the TOMRA is based on an instrument (TOSRA) with an equally strong background, it was important that various factor, reliability, and validity analyses be performed for my data for two reasons. First, each time a survey is implemented, it involves a different sample of individuals in a different culture and time from past studies. These analyses were used in my study to ascertain whether the data gathered were reliable and valid and therefore suitable for further analyses. Secondly, each time the instruments are analysed via these methods, it adds to the rich history of the instruments and aids future researchers who are seeking information about these instruments.

4.2.1 Validity and Reliability Analyses for WIHIC

As stated in Chapter 2, the WIHIC learning environment instrument has a tremendous history of being a reliable and valid tool for investigating classrooms worldwide (Aldridge, Fraser, & Huang, 1999; Margianti, Fraser, & Aldridge, 2002; Raaflaub & Fraser, 2002; Zandvliet & Man, 2003). Table 4.1 shows the results of the factor analysis for the 56 items in seven scales for the WIHIC instrument when

used with 745 students in 34 classes in Southern California. Only factor loadings greater than .40 are reported in the table. As well, the bottom of Table 4.1 shows eigenvalues and percentage of variance for each scale of the instrument. Items are referred to by number, while the actual wording of the item can be found in Appendix A.

The factor analysis of the 56 items in the WIHIC instrument demonstrates a strong factor structure consistent with previous research (Aldridge & Fraser, 2000; Aldridge, Fraser, & Huang, 2000; Zandvliet & Man, 2003). The *a priori* seven-scale structure was replicated almost perfectly in that nearly all items have a factor loading of at least .40 on their own scale and less than .40 on all the other scales. The only exceptions are that, for the Student Cohesiveness scale, two items (Item 6 and 8) did not have a factor loading of greater than .40 on its own scale.

Even with this minor discrepancy for the Student Cohesiveness scale, the seven scales together account for nearly 60% of the variance and the eigenvalues are greater than 1 for each of the seven factors. All 56 items have factor loadings of less than .40 with all other scales except their own scale, while 54 of the 56 items having factor loadings greater than or equal to .40 with their own scale.

These results are a strong signal that the WIHIC's factor structure is clear and repeatable. The corroboration of the factor loadings, eigenvalues, and percentage of variance give us confidence in the power of the WIHIC instrument to measure components of the learning environment from the perspective of the student.

Table 4.1 --- Factor Loadings, Eigenvalues, and Percentages of Variance for the What Is Happening In this Class? (WIHIC) Questionnaire

Item #	Factor Loading						
	Student Cohesiveness	Teacher Support	Involvement	Investigation	Task Orientation	Cooperation	Equity
1	.74						
2	.70						
3	.61						
4	.78						
5	.59						
6	---						
7	.61						
8	---						
9		.67					
10		.72					
11		.69					
12		.61					
13		.76					
14		.79					
15		.71					
16		.59					
17			.74				
18			.79				
19			.65				
20			.73				
21			.60				
22			.67				
23			.43				
24			.56				
25				.75			
26				.67			
27				.78			
28				.64			
29				.82			
30				.79			
31				.81			
32				.78			
33					.66		
34					.72		
35					.72		
36					.63		
37					.71		
38					.64		
39					.68		
40					.70		
41						.52	
42						.68	
43						.67	
44						.70	
45						.76	
46						.77	
47						.64	
48						.66	
49							.68
50							.68
51							.68
52							.76
53							.75
54							.78
55							.67
56							.74
Eigenvalue	1.65	1.87	1.76	15.13	3.10	4.00	5.59
% of Variance	2.94%	3.34%	3.15%	27.01%	5.54%	7.15%	9.99%

Only factor loadings greater than .40 are shown.
Sample of 745 students in 34 classes

Reliability analysis was carried out using Cronbach's alpha coefficient. Table 4.2 shows that the alpha coefficients for the different scales of the WIHIC were high when two units of analysis (the student and class mean) were used. When using the individual as the unit of analysis, reliability values ranged from .82 to .91. Using the class mean as the unit of analysis, the reliability coefficients were acceptable as they ranged from .75 to .96. These results reflect a reliable instrument with a strong level of internal consistency.

Table 4.2 --- Internal Consistency Reliability (Cronbach Alpha Coefficient), Discriminant Validity (Mean Correlation With Other Scales) and Ability to Differentiate Between Classrooms (ANOVA Results) for Two Units of Analysis for the WIHIC

Scale	Unit of Analysis	Alpha Reliability	Mean Correlation with other Scales	ANOVA Eta ²
<i>Student Cohesiveness</i>	Individual	.82	.37	.05
	Class Mean	.75	.35	
<i>Teacher Support</i>	Individual	.90	.41	.12**
	Class Mean	.94	.46	
<i>Involvement</i>	Individual	.88	.41	.08**
	Class Mean	.89	.45	
<i>Investigation</i>	Individual	.91	.30	.06
	Class Mean	.91	.44	
<i>Task Orientation</i>	Individual	.88	.35	.12**
	Class Mean	.94	.50	
<i>Cooperation</i>	Individual	.90	.44	.12**
	Class Mean	.91	.54	
<i>Equity</i>	Individual	.91	.38	.11**
	Class Mean	.96	.51	

** $p < .01$

The sample consisted of 745 students in 34 classes in Southern California.

The eta² statistic (which is the ratio of 'between' to 'total' sums of squares) represents the proportion of variance explained by class membership.

The mean correlation of a scale with the other scales was used as a convenient index of discriminant validity of each WIHIC scale. The discriminant validity for this use of the WIHIC (Table 4.2) was higher than would be hoped for, but does not exceed acceptable limits. The mean correlation of a scale with other scales ranges from .30 to .44 at the individual level, and from .35 to .54 at the class

mean level. We can conclude that the raw scores are independent, but with some level of overlap, while the factor analysis attests to independence for the factor scores. The results of the discriminant validity analyses could signal a possible situation involving multicollinearity that could affect the results of the multiple regression modelling phase of the data analysis. For this reason, multicollinearity is discussed further in Section 4.4.1.

The ability to differentiate between classrooms is another desirable characteristic of any classroom environment scale. Ideally, students within the same classroom should hold relatively similar perceptions, but average class perceptions should vary from classroom to classroom. In order to investigate this characteristic, an ANOVA was used for each WIHIC scale with class membership as the main effect. The resulting statistic, called the eta² statistic, is the ratio of 'between' to 'total' sum of squares and provides an estimate of the strength of the association between class membership and a WIHIC scale. A significant difference from ANOVA provides information about a WIHIC scale's ability to differentiate significantly between the perceptions of students in different classes.

The eta² statistic (Table 4.2) for each WIHIC scale demonstrates that there are significant differences ($p < .01$) between the classrooms for all the scales except Student Cohesiveness and Investigation. The range of values for the eta² statistic is between .05 and .12 for different WIHIC scales. Student Cohesiveness might not be different from class to class as it is potentially more influenced by peer relations than by what takes place in a specific classroom. If this is the case, then the results of having uniformity among the classes in this area would be plausible, and no distinct difference between the classes would be found.

The lack of a significant difference between classes for the Student Cohesiveness and Investigation scales is also consistent with the magnitudes of the standard deviations found for each scale using the individual student as the unit of analysis. As shown in Table 4.3, these two scales had the lowest standard

deviation of all WIHIC scales. This could suggest a similarity in the means in different classes which would make it difficult to differentiate between classes on these scales.

Table 4.3 --- Item Means and Standard Deviations for WIHIC, TOMRA, and RMARS Scales Using the Individual as the Unit of Analysis

Scale	<i>M</i>	<i>SD</i>
WIHIC (1=Almost Never Happens ... 5=Almost Always Happens)		
<i>Student Cohesiveness</i>	3.98	.16
<i>Teacher Support</i>	3.63	.32
<i>Involvement</i>	2.90	.25
<i>Investigation</i>	2.51	.23
<i>Task Orientation</i>	4.21	.28
<i>Cooperation</i>	3.72	.27
<i>Equity</i>	4.31	.29
TOMRA (1=Strong Negative Attitude ... 5=Strong Positive Attitude)		
<i>Enjoyment of Mathematics Lessons</i>	2.65	.31
<i>Normality of Mathematicians</i>	3.48	.19
RMARS (1=Not at all anxious ... 5=Extremely anxious)		
<i>Learning Mathematics Anxiety</i>	1.84	.29
<i>Mathematics Evaluation Anxiety</i>	2.69	.38

Overall, the WIHIC instrument held up very well in the various validity, reliability, and factor analyses. The seven-scale factor structure was confirmed with nearly all items loadings greater than .40 on their own scale and with no item having a factor loading greater than .40 on more than one scale. With the majority of the internal consistency coefficients higher than .85 for each unit of analysis, the WIHIC appears to be a reliable instrument when used with this sample. Discriminant validity values are low enough (all less than .54) to indicate a reasonable level of scale independence. Five of the seven scales were able to differentiate between the perceptions of students in different classrooms.

These results suggest that the WIHIC appears to be valid in high school mathematics classes in Southern California. My results compares favourably with other research that has involved factor and reliability analyses of the WIHIC in various countries and situations including Western Australia (Zandvliet & Straker, 2001), Canada (Raaflaub & Fraser, 2002; Zandvliet & Straker, 2001), Brunei Darussalam (Khine & Fisher, 2001, 2002; Riah & Fraser, 1998), Indonesia (Margianti, Fraser, & Aldridge, 2002; Soerjaningsih, Fraser & Aldridge, 2001), Singapore (Chua, Wong, & Chen, 2001; Fraser & Chionh, 2000), Malaysia (Zandvliet & Man, 2003), Taiwan (Aldridge, Fraser, & Huang, 1999), South Africa (Ntuli, Aldridge, & Fraser, 2003), Korea (Kim, Fisher, & Fraser, 2000), and in the United States (Martin-Dunlop & Fraser, 2004; Moss & Fraser, 2001; Pickett & Fraser, 2004). These results also are in agreement with recent confirmatory factor analysis on the WIHIC (Dorman, 2003).

4.2.2 Validity and Reliability Analyses for TOMRA

The Test of Science-Related Attitudes (TOSRA) was designed by Fraser in 1981 around seven scales which attempted to delineate meanings associated with various attitudes students have towards science (Adolphe, Fraser, & Aldridge, 2003; Aldridge, Fraser, & Huang, 1999; Waldrip & Fisher, 2001). The TOMRA attitude instrument used in my research is an adapted version of the TOSRA measuring mathematics-related attitudes instead of science attitudes. In order to adapt the TOSRA to measure mathematics attitudes, whenever the term ‘science’ was mentioned in the instrument it was replaced with the term ‘mathematics’. Of the original seven scales, four were chosen for my study: Enjoyment of Mathematics Lessons, Adoption of Mathematics Attitudes, Attitudes Towards Mathematics, and Normality of Mathematicians. These four areas seemed to have the strongest possible connection to the learning environment as I looked at the potential scales available in the TOSRA.

Each of the questions is answered using a five-point Likert response scale ranging from Strongly Agree to Strongly Disagree. Some questions are phrased in a negative fashion, which requires a reverse scoring of the responses in order to determine a scale score for a factor. A complete copy of the instrument can be found in Appendix B.

The factor analysis for the 40 TOMRA items in four scales revealed that two of the four *a priori* factors should not be retained for my research. The Adoption of Mathematics Attitudes and Attitudes Towards Mathematics Inquiry scales did not form separate factors and their items therefore were eliminated from further consideration in my research. Table 4.4 shows the factor loadings, eigenvalues, and percentages of variation for the remaining two scales: Enjoyment of Mathematics Lessons and Normality of Mathematicians.

Factor loadings for the 10 items in the Enjoyment of Mathematics Lessons scale and the 9 items in the Normality of Mathematicians scale were greater than .40 with their own scale, but less than .40 with the other factor. Item 1 did not have a factor loading greater than .40 with any scale and was also removed from further consideration in my study. Both factors had high eigenvalues (8.68 and 3.49, respectively). The percentage of variance ascribed to each scale was 21.69% and 8.72%, respectively, making a total of 30.41%.

Eigenvalues and visual analysis of a scree plot seemed to also point to two other factors from the TOMRA but, interestingly, they were distinguished by the way the questions in the factors were composed. The suggested factors were entirely composed of either positively- or negatively-worded questions from the remaining two original scales. Barnette (2000) showed that negatively-phrased questions in surveys might not always be productive and can appear as separate factors in the analysis even though they clearly do not measure the same area. Therefore, these two factors also were also eliminated from further consideration in my study.

Table 4.4 --- Factor Loadings, Eigenvalues, and Percentages of Variance for the Test of Mathematics Related Attitudes (TOMRA)

Item No.	Factor Loading	
	<i>Enjoyment of Mathematics Lessons</i>	<i>Normality of Mathematicians</i>
1	----	
4	.77	
8	.80	
12	.60	
16	.82	
20	.77	
24	.50	
28	.81	
32	.70	
36	.80	
40	.72	
5		.45
9		.53
13		.64
17		.65
21		.69
25		.53
29		.67
33		.54
37		.55
Eigenvalue	8.68	3.49
% of Variance	21.69%	8.72%

Only factor loadings greater than .40 are listed.
Sample of 745 students in 34 classes

The remaining two scales of the TOMRA demonstrate high internal consistency reliability coefficients (Table 4.5) with both the individual and class mean as the unit of analysis. The Cronbach alpha coefficient for Enjoyment of Mathematics Lessons is .92 for the individual level of analysis and .95 for the class mean as the unit of analysis. Cronbach's reliability coefficient for the Normality of Mathematicians factor is .79 with the individual as the unit of analysis and .90 with the class mean as the unit of analysis.

Table 4.5 --- Internal Consistency Reliability (Cronbach Alpha Coefficient) and Discriminant Validity (Correlation Between Scales) for Two Units of Analysis for the TOMRA

Scale	Number of Items	Unit of Analysis	Alpha Reliability	Correlation with other Scale
<i>Enjoyment of Mathematics Lessons</i>	10	Individual	.92	.59
		Class Mean	.95	.50
<i>Normality of Mathematicians</i>	9	Individual	.79	.59
		Class Mean	.90	.50

The sample consisted of 745 students in 34 classes in Southern California.

The discriminant validity, as indexed by the correlation between scales, is relatively high (.50 and .59) at the two different levels of analysis for the two attitude scales. However, the factor analysis confirms that the factor scores on the scales are measuring distinct constructs. (The ability to differentiate between classrooms analysis was not performed for the TOMRA as this type of analysis is only relevant for classroom environment scales.)

While the entire attitude instrument did not survive the factor analysis, the remaining two factors are very important in relation to mathematical instruction. The *Enjoyment of Mathematics Lessons* and the *Normality of Mathematicians* scales do give us a basis for investigating students' attitudes towards mathematics. The *Normality of Mathematicians* factor is especially interesting as this is the first time that this type of attitude has been used in research within mathematics education. The results of the reliability and validity analyses of the TOMRA suggests that the two remaining factors are appropriate for use in Southern California's high-school mathematics classrooms and will enable researchers to monitor attitudes towards mathematics in a meaningful way.

4.2.3 *Validity and Reliability Analyses for the RMARS*

The RMARS has shown itself to be a highly reliable and valid instrument in measuring mathematics anxiety for the past 20 years. As previously discussed

in Chapter 2, the original RMARS consisted of 96 items measuring two different scales involving mathematics anxiety. The updated version of the RMARS used in my research consists of 24 questions regarding the two *a priori* scales called Learning Mathematics Anxiety (LMA) and Mathematics Evaluation Anxiety (MEA). Questions from Plake and Parker's (1982) original instrument were updated for my study to reflect contemporary mathematics education technology, terminology, and methodology.

Again, a five-point Likert scale was used to measure the students' responses to the 16 items involved with LMA and the 8 items designed to investigate MEA. Responses range from Not At All Anxious to Very Anxious regarding the present feeling of the student about learning and evaluating mathematical knowledge. A complete copy of the version of the RMARS used in my research can be found in Appendix C.

The factor analysis from my study for the RMARS shows the same structure as in Plake and Parker's original version. Table 4.6 shows that over 50% of the variance in the instrument is attributable to the two factors (42.17% for LMA, 12.15% for MEA), and that each of the 24 items has a factor loading of less than .40 with the other scale but greater than .40 with its own scale. Therefore, the RMARS appears to have a factor structure that is well defined with my sample. This is also confirmed via the eigenvalues for each of the factors (10.12 for LMA and 2.92 for MEA, respectively).

Table 4.6 --- Factor Loadings, Eigenvalues, and Percentages of Variance for a Modified Version of the Revised Mathematics Anxiety Ratings Scale (RMARS)

Item No.	Factor Loading	
	<i>Learning Mathematics Anxiety</i>	<i>Mathematics Evaluation Anxiety</i>
1	.68	
2	.53	
5	.60	
6	.55	
7	.74	
8	.69	
9	.77	
10	.69	
11	.70	
12	.65	
13	.66	
15	.63	
21	.42	
22	.65	
23	.75	
24	.51	
3		.75
4		.77
14		.81
16		.69
17		.53
18		.87
19		.71
20		.86
Eigenvalue	10.12	2.92
% of Variance	42.17%	12.15%

Only factor loadings greater than .40 are listed.
Sample of 745 students in 34 classes

The RMARS also demonstrates high internal consistency reliability as measured via the Cronbach alpha coefficient (Table 4.7). The Learning Mathematics Anxiety scale has an alpha value of .92 using the individual as the unit of analysis and .96 with the class mean as the unit of analysis. Likewise, the Mathematics Evaluation Anxiety scale has high alpha reliability coefficients also (.91 for the individual level and .94 for the class mean level). These high values provide a confidence in using the instrument to measure these two types of mathematics anxiety in Southern Californian high schools.

Table 4.7 --- Internal Consistency Reliability (Cronbach Alpha Coefficient) and Discriminant Validity (Correlation Between Scales) for Two Units of Analysis for the RMARS

Scale	Number of Items	Unit of Analysis	Alpha Reliability	Correlation with other Scale
<i>Learning Mathematics Anxiety</i>	16	Individual	.92	.33
		Class Mean	.96	.58
<i>Mathematics Evaluation Anxiety</i>	8	Individual	.91	.33
		Class Mean	.94	.58

The sample consisted of 745 students in 34 classes in Southern California.

The discriminant validity of the RMARS, as measured by the correlation with between scales, has relatively low values (Table 4.7). The correlation between the scales using the individual as the unit of analysis is .33, while the value is .58 when the class mean is used in the analysis. While this suggests some overlap in the raw scores on the two factors, the factor analysis provides strong support for the independence of factor scores on the two anxiety scales.

The results of the factor, reliability, and validity analysis are consistent with previous research using the RMARS or the parent version of the MARS (Blum & Staats, 1999; Capraro, Capraro, & Henson, 2001; Hannafin, 1985; Plake & Parker, 1982; Richardson & Suinn, 1972), even with the modifications and updating that took place for my study. My data analyses continue to build the fine reputation of the RMARS and suggests that valid and reliable information on both kinds of mathematics anxiety is measured via this instrument and that it is appropriate for use in my study.

4.2.4 Summary of Validity and Reliability Analysis

The three instruments used in this research provide a strong foundation upon which to begin to look for associations between the scales that they measure. The *a priori* factor structure of both the WIHIC and RMARS instruments was replicated through the use of factor analysis. The reliability and discriminant validity analyses of each of these instruments suggests strong internal consistency

reliability values and acceptable correlations between scales with this sample of high school mathematics students.

The factor analysis of the TOMRA revealed that only two of the four original scales should be retained for use in my study. The two remaining scales of the TOMRA exhibit high Cronbach alpha coefficients and reasonable discriminate validity. The factor loading and reliability analyses for these three instruments gives credibility to the other analyses reported in this chapter concerning associations between learning environment, attitude and anxiety scales and gender differences in learning environments, attitudes and mathematics anxiety.

4.3 Gender Differences in Learning Environment Perceptions, Attitudes towards Mathematics, and Mathematics Anxiety

After the various analyses reported in Section 4.2 confirmed the validity and reliability of either the original or a revised version of each instrument, quantitative analyses of the data were performed in order to identify possible associations between, and gender differences in, these scales. For example, I analysed associations between the perceived learning environment and the level of mathematics anxiety and students' attitudes towards areas of mathematics, especially mathematics instruction and instructors.

Analyses were undertaken to determine possible gender differences in each learning environment, attitude, and anxiety scale by using a unit of analysis known as the 'within-class gender mean'. This unit of analysis involves calculating a matched pair of within-class means (male and female) for every class. The use of this unit of analysis avoids confounding when different classes have different proportions of males and females enrolled in them.

Using the within-class gender mean as the unit of analysis, gender differences for each scale were tested for statistical significance by using a simple

t-test for paired samples. Also, the effect size for the gender difference on each scale was determined to provide information about the magnitude of the difference. The definition of effect size, as well as a discussion of the modified Bonferroni statistical procedure which was used in the analyses, are found in Section 4.3.1. A report of the within-class gender analyses involving the learning environment scales follows in Section 4.3.2. The results for the attitude scales (4.3.3) and mathematics anxiety scales (4.3.4) follow immediately thereafter.

Finally, gender differences were also tested by using a multivariate analysis of variance (MANOVA) with the individual student as the unit of analysis. The method and rationale for this analysis will be discussed further in Section 4.3.5.

4.3.1 *Effect Size and Modified Bonferroni Procedure*

Effect size is used to determine the strength or magnitude of a difference between two samples, as distinct from its statistical significance. Cohen (1988) states that effect size is the difference between the two means, divided by a pooled standard deviation ($d = (M_1 - M_2) / SD_{pooled}$). This standardizes the difference between the means in terms of the number of standard deviations, and indicates the magnitude of a difference between variables as distinct from its statistical significance. The effect size helps to provide us with an indication of the educational importance of a potential difference.

Cohen (1988) goes on to state that effect size can be categorized as small ($d < 0.2$), medium ($0.2 < d < 0.8$), and large ($d > 0.8$), although he is hesitant in defining effect size in this way especially for diverse study areas like the behavioural sciences and education. Effect size is independent of the sample size. This is helpful as sample size can influence significance testing results (Carver, 1978). Wainer and Robinson (2003) have stated that the best use of effect size is in conjunction with traditional statistical significance testing as this combination

yields the most applicable results with the most meaning. Therefore, below I report both effect sizes and the results of the significance tests.

A statistical method was implemented in my study to ensure that statistical testing is not compromised by sample size or the number of tests that are performed. A modified Bonferroni principle is an acceptable statistical approach that safeguards from blindly accepting statistical differences, or lack thereof, that result from multiple *t*-testing.

The modified Bonferroni procedure (Holland & Copenhaver, 1988; Jaccard & Wan, 1996) was used in conjunction with paired *t*-tests in my study to determine statistical significance in multiple variable testing. This procedure was used because there can exist the increased chance of a Type I error due to simple probability of testing multiple pairs simultaneously.

This procedure ranks the probabilities obtained from the significance testing from smallest to largest (most significant to least). The first difference is considered significant if the *p*-value is smaller than the desired alpha (.05 or .01) after the *p*-value has been multiplied by the total number of test performed (*n*). The second difference is considered significant if the *p*-value is smaller than the desired alpha after multiplying by *n*-1. This continues by multiplying each successive *p*-value by the next *n*-*k* until a statistically nonsignificant result is obtained, thereby guaranteeing that the remaining values are also not significantly different (Holland & Copenhaver, 1988; Jaccard & Wan, 1996).

For example, in my study I compared males and females on eleven different scales assessing classroom environment, attitudes, and anxiety. In order not to have significant results purely due to simple probability, the smallest *p*-value was multiplied by 11 and compared to the desired alpha to determine if there really was a significant difference. The next smallest *p*-value was multiplied by 10 and so on. This continued until a nonsignificant difference was found.

4.3.2 Within-class Gender Differences in Learning Environment Perceptions

The average item mean, average item standard deviation, effect size, and results for a *t*-test for paired samples results for within-class gender differences in each WIHIC scale are shown in Table 4.8. Differences, both those that are and those that are not statistically different, can inform us about the way in which males and females differ in their views of various components of the learning environment, attitudes, and mathematics anxiety.

The average item mean is the scale mean divided by the number of items in the scale. For example, the average item mean for males for Student Cohesiveness is 3.89. This means that the average score for the items assessing Student Cohesiveness was nearly 4, or was close to the 'Often' response. Because each of the scales does not consist of the same number and therefore does not have the same maximum total scale score, the average item mean allows us to compare different scales meaningfully.

Table 4.8 --- Average Item Mean, Average Item Standard Deviation, and Gender Difference (Effect Size (*d*) and *t* Test for Paired Samples) for Classroom Environment, Attitudes, and Mathematics Anxiety using the Within-class Gender Mean as the Unit of Analysis

Scale	<i>M</i>		<i>SD</i>		Difference	
	Male	Female	Male	Female	<i>d</i>	<i>t</i>
WIHIC						
<i>Student Cohesiveness</i>	3.89	4.07	.22	.23	0.80	3.19 *
<i>Teacher Support</i>	3.52	3.70	.35	.41	0.47	2.50
<i>Involvement</i>	2.94	2.85	.31	.35	0.27	1.26
<i>Investigation</i>	2.57	2.44	.31	.37	0.38	1.66
<i>Task Orientation</i>	4.02	4.34	.41	.28	0.93	5.19 **
<i>Cooperation</i>	3.50	3.87	.42	.35	0.96	4.04 **
<i>Equity</i>	4.20	4.40	.41	.30	0.56	3.04 *
TOMRA						
<i>Enjoyment of Mathematics Lessons</i>	2.64	2.64	.30	.40	0.00	0.01
<i>Normality of Mathematicians</i>	3.40	3.56	.29	.22	0.63	-2.56
RMARS						
<i>Learning Mathematics Anxiety</i>	1.91	1.77	.36	.32	0.41	2.25
<i>Mathematics Evaluation Anxiety</i>	2.59	2.77	.47	.48	0.38	-2.10

* $p < .05$ ** $p < .01$ (Using modified Bonferroni procedure with 11 tests)

Sample of 745 students in 34 classes

Effect Size calculated by $d = (M_1 - M_2) / SD_{pooled}$

The within-class gender means analysis yielded some findings that were predictable, but others that were not. After using Bonferroni's correction, there were statistically significant gender differences in classroom learning environment for the WIHIC scales of Student Cohesiveness ($t = 3.19, p < .05$), Task Orientation ($t = 5.19, p < .01$), Cooperation ($t = 4.04, p < .01$), and Equity ($t = 3.04, p < .01$).

The effect sizes for the four learning environment scales that were shown to have a statistically significant difference were all in the moderate to high range (Cohen, 1988). Task Orientation ($d=0.93$) and Cooperation ($d=0.96$) were found to have high effect sizes and thereby reflect a strong difference between the genders in these areas. Student Cohesiveness ($d=0.80$) and Equity ($d=0.56$) were found to have moderate effect sizes. This suggests that the differences are genuine, yet moderate in their strength.

The differences in the means for Student Cohesiveness, Task Orientation, and Cooperation are all higher for the females than the males. As females of high-school age seem to be more social and interactive than males, as well as slightly more motivated as a group regarding academic achievement, these findings are fairly plausible as each of these scales has to do with motivation and interaction among the students. This replicates previous research into gender differences in learning environment perceptions using the WIHIC, where generally females have viewed the environment more favourably than males (Adolphe, Fraser, & Aldridge, 2003; Margianti, Fraser, & Aldridge, 2002; Moss & Fraser, 2001).

The finding of a difference between the genders on the Equity scale reflects an inconsistency with previous research in the field of learning environment and those in mathematics education. The result that females perceive a higher level of equity than the males is quite unexpected from a mathematics education viewpoint, but consistent with previous learning environment research (Adolphe, Fraser, & Aldridge, 2003; Margianti, Fraser, & Aldridge, 2002; Moss & Fraser,

2001). There has been a long and detailed look at gender equity in mathematics education during the past two decades, with the common theme being that females in high school mathematics classrooms do not feel that they are being treated equally (Levine, 1995; Meece, 1981; Tobias, 1978; Zettle & Raines, 2000). Yet, for my sample of high school students, the females perceive a higher level of equity in the classroom than do males.

It seems that the scales with higher effect size for gender differences are all involved with the motivation of individuals and the social structure of classrooms. Some of these differences might not be specific to mathematics classrooms, but rather a general social phenomenon common to most high school classrooms, regardless of subject area.

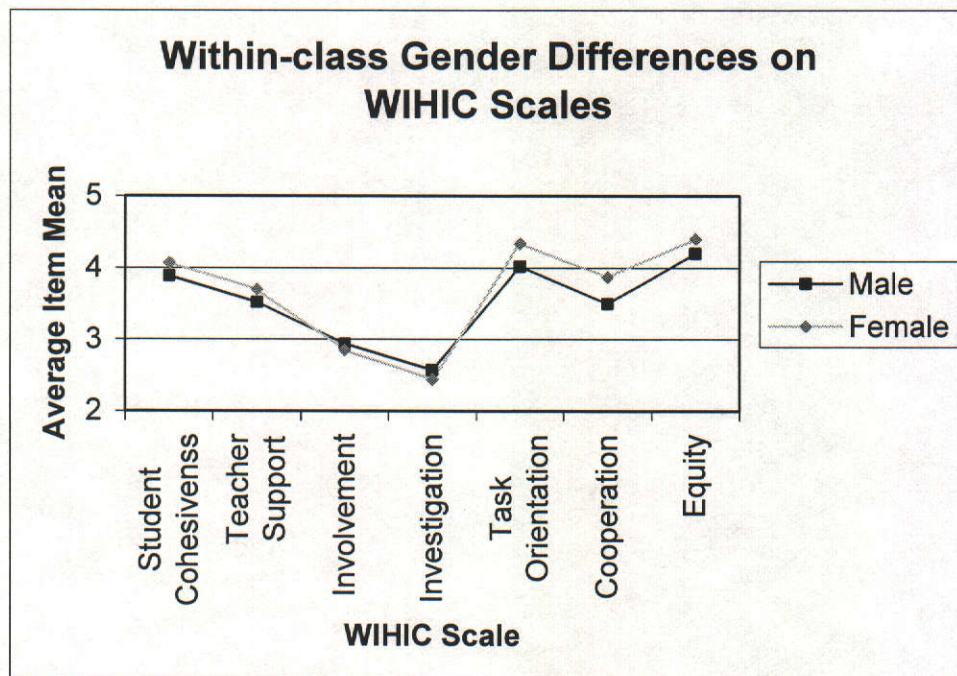


Figure 4.1 – Within-class Gender Differences on WIHIC Scales

There were no statistically significant differences between the within-class gender means in the classroom environment areas of Teacher Support, Involvement, and Investigation. As shown in Figure 4.1, the Involvement and

Investigation scales have quite low average item means (less frequent than the response alternative of Sometimes), which suggests that both male and female students do not feel that they are involved very often in classroom activities or in performing investigations.

The absence of a statistically significant difference between the genders in within-classroom perceptions of Teacher Support is a noteworthy result. Just as was mentioned earlier regarding the area of Equity, researchers (Cambell & Evans, 1997; Meece, Wigfield, & Eccles, 1990) have found that females in the mathematics classroom have consistently felt as if they are treated differently from the males, and that this can negatively influence their future mathematical endeavours and attitudes. Much in the same way that the perception of equity seems to be different in my sample of high school students, so the level of Teacher Support seems to have been positively impacted.

4.3.3 *Within-class Gender Differences in Attitudes*

Within-class gender differences in attitudes were also investigated using paired *t*-tests for samples with a modified Bonferroni correction, as well as effect sizes. The results of the TOMRA analyses seem to suggest that there is little difference between male and female attitudes in this set of classrooms with regards to attitudes towards mathematics (Table 4.8).

There was no significant within-class gender difference in Enjoyment of Mathematics Lessons scores and the effect size was zero as the means were identical. This interesting result suggests that the enjoyment, or possible lack thereof, of mathematics lessons is the same across gender boundaries within classrooms.

There was also no statistically significant difference between the genders for the Normality of Mathematicians scale, even though the effect size was in the

moderate range (namely, 0.63). One of the weaknesses of the Bonferroni method is that, while it reduces much of the Type I error in multiple testing, it is conservative in detecting differences and can introduce Type II error in its place. There is a possibility that the results of the Normality of Mathematicians scale falls into this weakness. It is worth noting that, while no statistically significant differences existed, the raw mean score for females for the Normality of Mathematicians scale was generally favourable for females in these classes.

The average item means for both males and females for the attitude scales help us to understand what the commonly-accepted mindset of high school students is towards mathematics classrooms (Figure 4.2). With an average item mean over 3.0 for both genders, it is worth noting that the students have a relatively favourable view of mathematicians and are generally positive towards them. On the other hand, the level of enjoyment of mathematics lessons is relatively low for these same students.

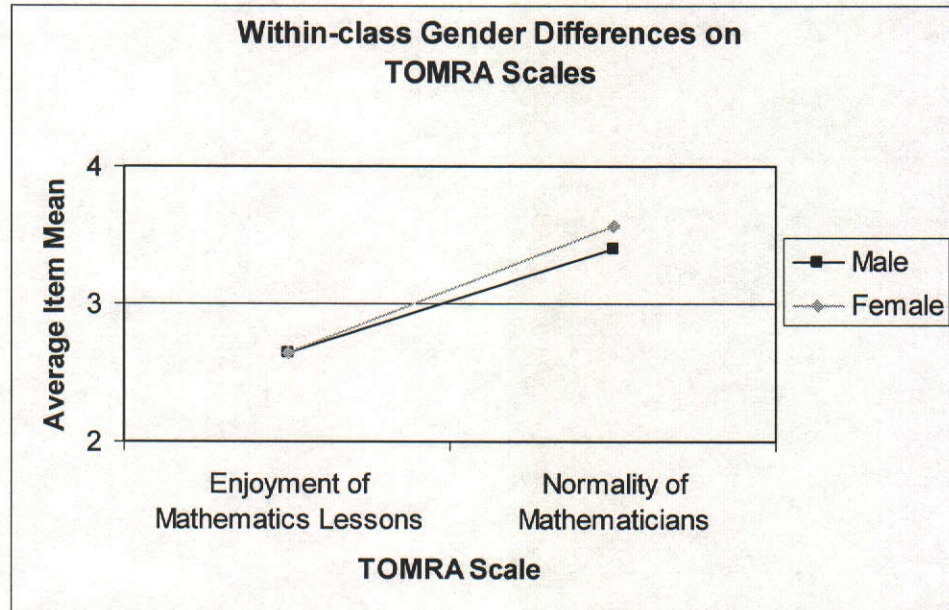


Figure 4.2 – Within-class Gender Differences on TOMRA Scales

The results of the analyses seem to suggest that there are no statistically significant gender differences in the attitudes towards mathematics lessons or

instructors. These results suggest that male and female students view those who are involved with mathematics, notably mathematics teachers in the high school setting, with about the same degree of normality, while both males and females seem to have the same level of enjoyment of mathematics lessons.

4.3.4 Within-class Gender Differences in Mathematics Anxiety

The results for the within-class gender differences in mathematics anxiety for the two RMARS scales (Table 4.8), again using paired *t*-tests with a modified Bonferroni correction and also effect sizes, show no statistically significant differences between the genders for either the Learning Mathematics Anxiety scale or the Mathematics Evaluation Anxiety scale. The effect size for each of these gender differences are relatively moderate as well (.41 and .38, respectively).

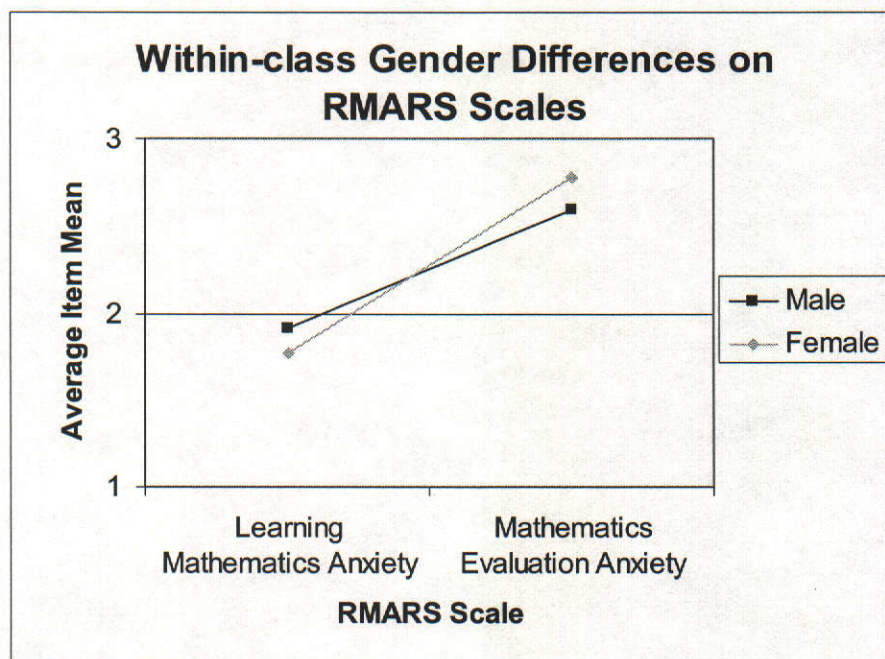


Figure 4.3 – Within-class Gender Differences on RMARS Scales

While there was no statistically significant difference between the genders for either of the anxiety scales, there is an interesting trend that can be seen from the data. The average item mean (Figure 4.3) for males in the Learning

Mathematics Anxiety scale are larger than females, but reversed in the Mathematics Evaluation Anxiety scale.

Because the effect size of each within-class gender difference for RMARS is moderate (0.41 and 0.38), this could again reflect a possible Type II error associated with the Bonferroni correction. If there were statistical differences, it would be an interesting notion that females are more anxious about the evaluation of their mathematical knowledge, but males are more anxious about the actual classroom situation during mathematics instruction. A larger sample size would increase the power of the statistical testing and could possibly yield a clearer answer to this interesting question.

4.3.5 *Gender Differences Using the Individual as the Unit of Analysis*

The previous analyses of gender differences by using within-class gender means allows investigation into the differences between males and females without the potentially confounding variable of the classroom coming into play. While this is proper and helpful, the lack of a substantial sample size can create a lack of power and possibly introduce Type II errors, as was previously mentioned. Because of this potential problem, it was decided to repeat the analyses for gender differences with the individual as the unit of analysis to further illuminate any differences.

Gender differences were examined by employing a multivariate analysis of variance (MANOVA). MANOVA simultaneously considers gender differences for all of the learning environment, attitude, and anxiety scales. Effect size was also computed to give further clarification of the strength of potential differences.

While the unit of analysis for the MANOVA was the individual student, the grade level of each student was also considered as an independent variable as well to see if there was an interaction between gender and grade level which could influence the results. Wilks' lambda (similar to a multivariate *F*-score) was

used to determine the statistical significance of differences in the set of scales as a whole.

The MANOVA involved the variables of gender and grade to determine if there were overall gender or grade differences in the set of eleven scales, as well as any interaction between gender and grade level. No interaction between grade and gender was identified in the MANOVA. Therefore this interaction was not investigated further. Only differences between the genders are reported in Table 4.9.

Because the Wilks' lambda criterion indicated statistically significant gender differences for the whole set of dependent variables, the univariate ANOVA was interpreted for each individual scale. The *F* ratio for each scale for gender differences is shown in Table 4.9 also.

Table 4.9 --- Average Item Mean, Average Item Standard Deviation, and Gender Difference (Effect Size and MANOVA Results) for Classroom Environment, Attitudes, and Mathematics Anxiety using the Individual as the Unit of Analysis

Scale	<i>M</i>		<i>SD</i>		Difference	
	Male	Female	Male	Female	<i>d</i>	<i>F</i>
WIHIC						
<i>Student Cohesiveness</i>	3.85	4.00	.66	.69	0.22	8.46 *
<i>Teacher Support</i>	3.42	3.62	.86	.85	0.23	9.27 *
<i>Involvement</i>	2.86	2.79	.86	.83	0.01	1.31
<i>Investigation</i>	2.55	2.40	.87	.84	0.17	4.70
<i>Task Orientation</i>	4.01	4.28	.75	.63	0.39	23.79 **
<i>Cooperation</i>	3.47	3.72	.87	.87	0.28	16.03 **
<i>Equity</i>	4.16	4.35	.81	.75	0.24	7.63 *
TOMRA						
<i>Enjoyment of Mathematics Lessons</i>	2.77	2.74	.86	.88	0.03	0.75
<i>Normality of Mathematicians</i>	3.47	3.60	.56	.52	0.24	0.73
RMARS						
<i>Learning Mathematics Anxiety</i>	1.94	1.80	.78	.67	0.19	8.85 **
<i>Mathematics Evaluation Anxiety</i>	2.55	2.74	.97	1.04	0.19	5.72 *

* $p < .05$ ** $p < .01$

Sample of 745 students in 34 classes

Effect Size calculated by $d = (M_1 - M_2) / SD_{pooled}$

Furthermore, as grade level was not a variable of interest in my study, any results for grade level differences were ignored. Only the gender-grade level

interaction was pertinent to my research but, as mentioned previously, no significant interaction was identified.

For the WIHIC, five of the seven scales were found to have significant differences between the genders at the individual level. Task Orientation ($F = 23.79, p < .01$), Cooperation ($F = 16.03, p < .01$), Student Cohesiveness ($F = 8.46, p < .05$), and Equity ($F = 7.63, p < .05$) each showed significant gender differences in that females' perceptions were similar to those found in the within-class gender analysis. The effect size for each of these differences was in the moderate range as well (.39, .28, .22, and .24, respectively).

The fifth scale that was found to be significantly different for males and females, when using the individual as the unit of analysis, was Teacher Support ($F = 9.27, p < .05$). This result differs from that found with the within-class gender analysis which revealed no statistically significant difference, although a moderate effect size still was present. While the effect size for Teacher Support was a moderate .23, there is evidence that there could be a possible difference between the genders in this area.

Again, the gender differences for Teacher Support and Equity at the individual level of analysis point to some surprising and interesting findings, similar to those from the analyses of within-class gender differences. Overall, it seems that, relative to males, females in this sample were more positive regarding the level of teacher support and equity in their high school mathematics classrooms than has been previously reported in other mathematics education research (Levine, 1995; Meece, 1981; Tobias, 1978; Zettle & Raines, 2000). While this is surprising when compared to research involving mathematics education, it has been a common finding when the WIHIC was used to measure learning environment perceptions in past studies (Adolphe, Fraser, & Aldridge, 2003; Margianti, Fraser, & Aldridge, 2002; Moss & Fraser, 2001).

The MANOVA results for the TOMRA (Table 4.9) show that there were no significant gender differences for either the Enjoyment of Mathematics Lessons scale or the Normality of Mathematicians scale when using the individual as the unit of analysis. This again seems to be consistent with the within-class gender means analysis. This would suggest that the students' attitudes towards mathematics lessons are independent of gender.

The MANOVA results for the RMARS (Table 4.9) reveal differences for the Learning Mathematics Anxiety ($F = 8.85, p < .05$) as well as for the Mathematics Evaluation Anxiety scale ($F = 5.72, p < .05$). This is different from the findings obtained through the within-class gender analysis, although the effect size from the MANOVA were relatively small. When the within-class gender mean was used as the unit of analysis, both of the mathematics anxiety scales registered moderate effect sizes and the nonsignificant findings could have been a result of the conservative Bonferroni correction that was used during that investigation. The interesting interpretation of these new findings is that females are more anxious than males regarding testing of mathematical concepts, but that males are more anxious regarding the learning of the mathematics in the classroom context.

4.3.6 *Summary of Gender Differences in Learning Environment Perceptions, Attitudes, and Anxiety*

The analyses of the gender differences using the within-class gender mean and the individual as the units of analysis yield some surprising results and some that could be expected.

For the WIHIC scales, there were statistically significant gender differences in the areas of Student Cohesiveness, Task Orientation, Cooperation, and Equity when using the within-class gender mean as the unit of analysis. These areas were also associated with significant gender differences when the individual was used as the unit of analysis, but also included a difference in the area of Teacher Support as well. There were no differences between the genders for the scales of

Involvement or Investigation using either unit of analysis. This could have been caused by the relatively low prevalence of each scale that is perceived by the students originally. Gender differences in Equity and Teacher Support, while uncommon in mathematics education research, are consistent with past research in the field of learning environments.

The analyses for the TOMRA scales data revealed no significant differences between the genders for either of the two scales that are measured with this instrument. While there might not have been statistical significance, there are some interesting trends and possibilities that could be consistent with this information. The level of enjoyment of mathematics lessons was similar across the genders for the analysis involving both individual and the within-class mean, and students' perceptions of the normality of mathematicians seem to be fairly positive for both males and females.

For mathematics anxiety as measured by the RMARS, no significant differences were found for either scale (Learning Mathematics Anxiety or Mathematics Evaluation Anxiety) using the within-class gender mean as the unit of analysis. However, significant gender differences emerged for both scales when the individual was used as the unit of analysis (although effect sizes were small). Especially interesting is the finding that males seem to feel more anxiety with regards to the mathematics learning environment, but females felt more anxiety with regards to the evaluation of the mathematics content.

4.4 Associations between Classroom Learning Environment Dimensions, Mathematics Anxiety and Attitudes towards Mathematics

Within the field of learning environments, there is a strong tradition of investigating associations between various components of the environment and other areas of the educational system and operation (Dorman, 2001; Khine & Fisher, 2001, 2002; Zandvliet & Man, 2003). In particular, there has also been a

strong history of looking at the relationships between learning environments and attitudes towards a specific subject area (Adolphe, Fraser, & Aldridge, 2003; Wong & Fraser, 1996). Consistent with these traditions, my study attempted to identify relationships and associations between the learning environments of high school students and their levels of mathematics anxiety and attitudes towards mathematics.

Associations between the learning environment scales and the mathematics anxiety and attitude scales were investigated through simple correlation and multiple regression analyses with the learning environment scales serving as independent variables and the RMARS/TOMRA scales as the dependent variables. The correlation analysis involved simple Pearson product-moment correlations which identify the bivariate relationship between each anxiety/attitude scale and each learning environment scale.

Also, a multiple regression analysis was conducted for each of the attitude and anxiety scales. This analysis identifies the relationship of the anxiety/attitude scale as dependent variable with the set of learning environment scales as independent variables. Through this method, a linear equation gives us a mathematical model for how the various components of the learning environment jointly impact on the independent variable. In particular, the regression coefficient indicates the unique contribution made by a specific learning environment dimension in explaining the variance in the dependent variable when all the learning environment scales are mutually controlled.

4.4.1 Associations between Anxiety and Learning Environment

Table 4.10 shows the results of the correlation and multiple regression analyses between each of the two mathematics anxiety scales and the set of learning environment scales. The correlation coefficient (r) and the multiple

regression coefficients (β) are shown for each of the learning environment scales. The multiple regression coefficient (R) is also shown for each of the relationships.

Mathematics Evaluation Anxiety shows no significant relationships with classroom environment for either the simple correlation or multiple regression analyses. It appears that specific emphasis in the learning environment in these classes did not contribute to anxiety associated with the evaluation process. This is not totally unexpected. The evaluation process for testing of mathematics knowledge is probably not as dependent on the classroom situation and environment as much as the personal motivation and goals of each student.

Table 4.10 --- Simple Correlation and Multiple Regression Analyses for Associations Between Anxiety and Classroom Environment Using the Individual as the Unit of Analysis

Environment Scale	Learning Mathematics Anxiety		Mathematics Evaluation Anxiety	
	r	β	r	β
<i>Student Cohesiveness</i>	-0.13 **	-0.14 **	-0.04	-0.13
<i>Teacher Support</i>	-0.04	-0.00	0.03	0.00
<i>Involvement</i>	0.01	0.04	-0.00	-0.00
<i>Investigation</i>	0.06	0.01 *	0.01	0.00
<i>Task Orientation</i>	-0.09 *	-0.01 *	-0.03	-0.01
<i>Cooperation</i>	-0.08 *	0.01	0.02	0.01
<i>Equity</i>	-0.07	-0.01	0.02	0.00
Multiple Correlation, R		0.17 **		0.10

* $p < 0.05$ ** $p < 0.01$

While the simple correlations between the Learning Mathematics Anxiety and the classroom environment scales were not strong, there were significant negative relationships for the scales of Student Cohesiveness ($p < .01$), Cooperation ($p < .05$), and Task Orientation ($p < .05$). This suggests that there is a moderate level of relationship between anxiety with the process of learning mathematics and these three learning environment areas.

The strongest correlation between learning environment and Learning Mathematics Anxiety is in the area of Student Cohesiveness. As all the significant

correlation values are negative, this would suggest that, as a student perceives a higher level of group support and connection with his/her classmates, then the level of anxiety in that setting is lower. Likewise, Task Orientation and Cooperation have significant negative correlations with the Learning Mathematics Anxiety scale. As perceptions of priority and dedication towards the subject or school increase (Task Orientation), as well as the level of cooperation that is felt in the classroom (Cooperation), then the less likely it is that a student is anxious about the situation and environment surrounding mathematics lessons and the classroom.

The multiple regression analysis using Learning Mathematics Anxiety as the dependent variable and the WIHIC scales as the predictor variables yielded a statistically significant multiple correlation of 0.17 ($p < .01$). Three classroom environment scales were found to be significant independent predictors of Learning Mathematics Anxiety, with Student Cohesiveness ($p < .01$) being the strongest and having a negative coefficient. This suggests that the less Student Cohesiveness that there is in a classroom, the more anxiety there is likely to be in the process of learning mathematics when all other WIHIC scales are mutually controlled.

The other two scales with significant beta coefficients for the Learning Mathematics Anxiety model were Investigation and Task Orientation ($p < .05$). These results suggest that more Investigation and less Task Orientation are associated with more anxiety towards mathematics when the other WIHIC scales are mutually controlled.

This model paints a picture of classrooms where the sense of peer interaction and acceptance (Student Cohesiveness) is extremely important in the learning process, as is motivation and time on task (Task Orientation). This also suggests that the idea of more investigation could raise anxiety in classrooms, maybe because either these students have not experienced the joy of discovery in

the mathematics context previously, or they have been trained through years of passive instruction not to see the value in, and even fear the possibility of, participating in this endeavour.

The low multiple correlations in Table 4.10 might have arisen partly because of multicollinearity, which exists when the independent variables possess a high level of correlation with each other. This can reduce the precision of the coefficients in the analysis (Butler & McNertney, 1991; Pearce & Reiter, 1985). As shown in Table 4.2, intercorrelations between the WIHIC scales are moderate as they range from 0.30 to 0.54. While not excessively high, these correlations are large enough to give rise to a degree of multicollinearity.

However, other researchers have argued that low multiple correlations can be meaningful (Schumacker, Mount, & Monahan, 2002) and simply reflect a weak underlying relationship between the dependent variable and the independent variables. The statistical significance of regression coefficients do not necessarily decrease under multicollinearity (Spanos & McGuirk, 2002).

4.4.2 *Associations between Attitudes and Learning Environment*

The simple correlation analyses of associations between the attitudes towards mathematics and learning environment scales also yielded some interesting findings (Table 4.11). There was only one WIHIC scale (Student Cohesiveness) that did not have a significant simple correlation with the Enjoyment of Mathematics Lessons factor. Because all significant correlations are positive, this would suggest a direct relationship between students' enjoyment of the mathematics lessons and the perceived learning environment.

The multiple correlation score between Enjoyment of Mathematics Lessons and the set of WIHIC scales is 0.33 and is statistically significant ($p < .01$). Inspection of the regression coefficients in Table 4.11 shows that Investigation and

Task Orientation are significantly ($p < .01$), independently, and positively related to Enjoyment of Mathematics Lessons when all the other learning environment scales are mutually controlled. This would suggest that, as students perceive more investigation in a classroom and that they are focused on their academic work, they feel a higher level of enjoyment. This is seemingly in contradiction with the findings previously recorded (Table 4.10) in which more Investigation was associated with higher Learning Mathematics Anxiety. This is possible because of conceptual differences between anxiety and enjoyment as they are not polar opposites. Instead, it is quite possible that one can enjoy an experience because it is new and different but, at the same time, can feel anxiety over the learning of material and interpretation of results.

Table 4.11 --- Simple Correlation and Multiple Regression Analyses for Associations Between Attitudes and Classroom Environment using the Individual as the Unit of Analysis

Environment Scale	Enjoyment of Mathematics Lessons		Normality of Mathematicians	
	<i>r</i>	β	<i>r</i>	β
<i>Student Cohesiveness</i>	0.05	-0.02	0.02	-0.02
<i>Teacher Support</i>	0.11 **	-0.02	0.10 **	0.01
<i>Involvement</i>	0.15 **	0.07	-0.01	-0.01 *
<i>Investigation</i>	0.18 **	0.14 **	0.04	0.06
<i>Task Orientation</i>	0.30 **	0.37 **	0.16 **	0.07
<i>Cooperation</i>	0.08 *	-0.01 *	0.05	-0.01
<i>Equity</i>	0.17 **	0.02	0.21 **	0.16 **
Multiple Correlation, <i>R</i>		0.33 **		0.22 **

* $p < 0.05$ ** $p < 0.01$

Also, Cooperation ($p < .05$) was found to have a significant and independent association with Enjoyment of Mathematics Lessons. This suggests that the level of enjoyment involved with mathematics lessons is greater when there is a smaller amount of Cooperation. While the level of cooperation that students perceive was moderate (Table 4.3), this finding might reinforce that some students prefer to work independently, especially in mathematics, and do not view cooperative techniques as enjoyable. Because the standardized multiple regression coefficient was very small (-0.01), the effect of the level of Cooperation would seem to be small.

While the simple correlations between the Normality of Mathematicians and the WIHIC scales were not as high as for the Enjoyment scale, they were significant for Teacher Support, Task Orientation, and Equity ($p < .05$). All of these statistically significant simple correlations are positive. These correlations seem plausible as the level of Normality of Mathematicians that a student feels would probably be connected to the personal support and connection with the teacher (Teacher Support and Equity), as well as the motivation and effort that each student demonstrates (Task Orientation).

The multiple regression analysis with Normality of Mathematicians as the dependent variable also had a significant multiple correlation of 0.22. Inspection of the regression coefficients revealed two WIHIC scales with significant beta coefficients, namely, Equity ($p < .01$) and Involvement ($p < .05$), when all of the other WIHIC scales are mutually controlled. This suggests that a higher level of Equity is linked with higher Normality of Mathematicians scores. This result is consistent with the social dynamics of teacher-student relationships. As the perception of fairness from a mathematics instructor grows, perhaps the image and attitude towards that instructor and all mathematicians become more favourable.

The negative and statistically significant independent association of the Normality of Mathematicians scale with Involvement is curious. It does not seem logical that, if the level of involvement during a class decreases, students' views of how 'normal' the mathematician/instructor would increase. The only logical reason for this would be that the typical adolescent might not view someone who is interested in mathematics as 'normal' and, when a student is asked to be involved directly in that learning process, he/she would view the mathematician or instructor as different or unique. Because the regression coefficient for this association is very small (-0.01), and because of the possibility that multicollinearity is present, this finding for Involvement should not be over-

interpreted. In order to gain a clearer understanding of this relationship, replication in future research will be needed.

4.4.3 *Summary of Associations of Anxiety and Attitudes with Learning Environment*

The results of the correlation and multiple regression analyses using the set of learning environment scales as independent variables, and the attitude/anxiety scales as dependent variables, yielded some interesting results. No learning environment scale was significantly related with Mathematics Evaluation Anxiety in either the simple correlation or multiple regression analyses.

The Learning Mathematics Anxiety scale was found to be negatively associated with the learning environment scales of Student Cohesiveness and Task Orientation in both the simple correlation and the multiple regression analyses. While Cooperation was found to have a significant negative correlation with the Learning Mathematics Anxiety scale, Investigation exhibited a statistically significant positive coefficient in the regression model.

Nearly all the learning environment scales were found to have significant simple correlations with the Enjoyment of Mathematics Lessons scale, with the only exception being Student Cohesiveness. The multiple regression analysis for Enjoyment of Mathematics Lessons revealed a significant, positive, and independent influence for Investigation and Task Orientation, and a significant, negative, and independent coefficient for Cooperation.

The analyses for the Normality of Mathematicians scale revealed significant simple correlations between attitudes and three learning environment scales: Teacher Support, Task Orientation, and Equity. The multiple regression model using Normality of Mathematicians as the dependent variable revealed a significant positive independent influence for Equity and a significant negative

independent influence for Involvement when all the learning environment scales were mutually controlled.

The implications of these findings are discussed further in the next chapter. These findings from the quantitative data are likely to enable us to view the interaction of the high school mathematics classroom environment with attitudes and anxiety in order to assist classroom instructors. These findings also could help us to more clearly discern areas of importance for the research community as well.

4.5 Qualitative Research Findings

The findings from the quantitative data seem to point to the importance of various components of the learning environment in terms of their influence on the anxiety and attitudinal levels of students. With this in mind, qualitative data were garnered to investigate some of these learning environment influences, to corroborate or refute findings from the quantitative data, and to find nuances and details left uncovered by the survey data. Combining of quantitative and qualitative techniques has been popular in recent years of research involving learning environments (Aldridge, Fraser, & Huang, 1999; Fraser & Tobin, 1991; McKnight et al., 2000; Tobin & Fraser, 1998).

As previously mentioned in Chapter 3, 18 students from the sample (10 males, 8 females) were identified by their extreme level (high or low) of mathematics anxiety and interviewed regarding their anxiety about mathematics, as well as regarding associations between the perceived learning environment, attitudes, and anxiety in the mathematics classroom. Students were asked to participate in the interview based on whether their perceived level of anxiety was either unusually high or low. Each interview was recorded and transcribed verbatim. A sample of the interview questions and protocol is found in Appendix G.

The unit of analysis from the qualitative data involves verbatim quotations from the students regarding their anxiety, attitudes, or the learning environment (Miles & Huberman, 1984). A total of 165 quotes, varying in length from a sentence to a paragraph, were used as the raw data for the content analysis.

Analysis of the interview data was conducted following the inductive approach described by various authors (Miles & Huberman, 1984; Patton, 1990; Silverman, 2000). This approach identifies emergent themes from the quotes, building towards higher-order themes composed of combinations of lower themes. This process is similar to a conceptual factor analysis. Quotes with common themes were clustered together and labeled. I have called these initial themes, derived directly from the raw data, as 'Tier I' themes. Figure 4.4 illustrates this beginning step with examples from the quotations collected.

From these Tier I themes, the inductive process continues by looking for common threads between various Tier I themes, thereby forming a second, higher-order level called Tier II. For certain Tier II themes, a final combining of the themes was evident and the highest order of emergent themes was formed, known as Tier III. Some themes seemed to 'stand alone', and therefore the theme was moved into the Tier III position immediately.

The complete inductive content analysis is found in Figure 4.5. As can be seen in the figure, many of the emergent themes from the interviews were connected to the quantitative factors involving anxiety, attitudes, and the role of the learning environment in the mathematics classroom. Tier III levels include the familiar themes of Teacher Support, Evaluation and Test Anxiety, Student Cohesiveness and Cooperation, and Learning Mathematics Anxiety and Emotions. These all seem to connect directly to the quantitative data and their importance in some capacity during mathematics instruction.

Examples of Quotations	Tier I Theme	
<p>"There is always a right answer. It's exact."</p> <p>"I guess I like it to be more complicated. At least it is grabbing then. It's not more repetitive. You have to do something different, on more complicated problems."</p> <p>"It is different from other subjects because we learn new stuff here, like in every chapter we get new and different ideas how to solve problems."</p>	<p>Complexity of Mathematics</p>	
<p>"I guess that you can't really relate it to anything that you can do by yourself."</p> <p>"In math, it's more like how you think and how you get it, and not so much an outside perspective."</p> <p>"Math makes you think...it is a challenge. I like challenges because I have to sit there and work it out and that is what I like doing."</p> <p>"It makes you think more. The things that you have to study in a math class are just more difficult."</p>		<p>Mental Challenges of Mathematics</p>
<p>"I'm catching the basics now, but you have to pay attention all the time. You can't miss a single detail."</p> <p>"If you miss one step in a problem, then the whole thing is messed up. Once I put everything together, then I figured it all out."</p> <p>"If you don't understand one thing, then you don't understand the whole thing in Geometry."</p>		

Figure 4.4 -- Illustration of quotations clustering method

The one new area that emerged from the interviews was the theme of the Structure of Mathematical Content. The anxiety caused by the way mathematics builds upon itself, combined with the perceived complexity of mathematics, is evident in this theme. While this is not directly related to the learning environment, it does identify an important factor that students come into the mathematics classroom either worrying about or relishing.

The themes that emerged from the inductive analysis seem to confirm that the relationships identified in the quantitative data analyses are worthy of inspection. The statements made by students regarding their fears and feelings in the mathematics classroom tend to show that components of the classroom learning environment play a role in the development of mathematics anxiety and the attitude that students bring to the mathematics class.

While many of the quotes from students verbalized a fairly high level of comfort with mathematics, both in and out of the classroom, some of their responses to certain questions seem to be contradictory. These responses seem to point towards a difference between the outward verbalising of anxiety and the actual level of anxiety that a student feels inside. Each student was asked to describe a place outside school where they have the same kind of feeling that they do in the mathematics class. Below are a few of the students' answers:

It feels like I am driving in my car. When you drive, you have to be paying attention at all times and be focused on your driving, and in math class you have to focus on math. For the next hour of time, you have to focus on math. You can't veer off in another direction or you'll get lost! (Anna, 11th grade female)

I feel like I am going to play basketball at a park. You go over there and everyone knows what they are doing and you don't. Any situation, really, where people are really good at what they are doing and you have no idea, you're completely lost within your head. (Robert, 11th grade male)

It feels like I am at the orthodontist. I have to go there and it hurts and you're never going to get through it. Then you have to go back again and get more work done. (Julia, 10th grade female)

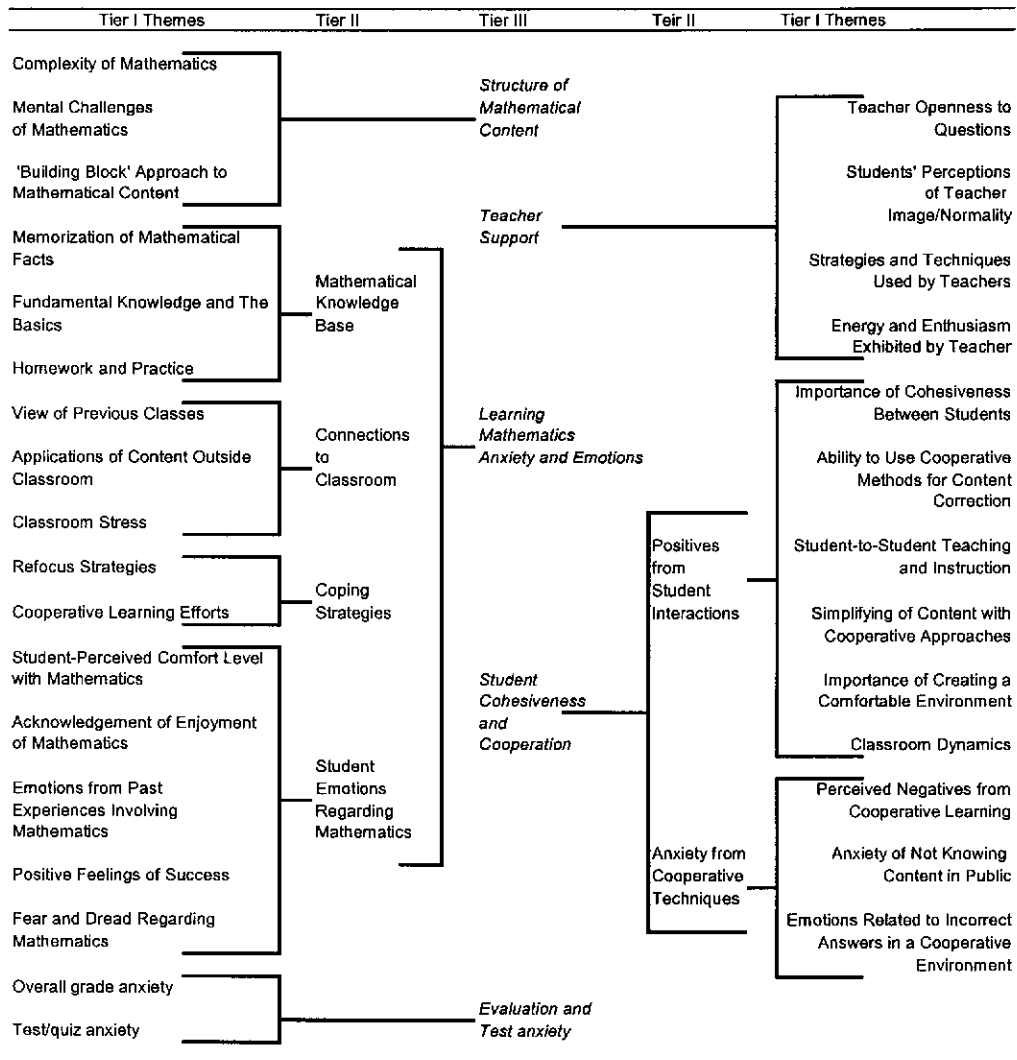


Figure 4.5 --- Complete Inductive Content Analysis Showing All Tier I, II, and III Emergent Themes Beyond the Quotation Level

While students want to believe that they can and will succeed in mathematics, their subconscious seems to be telling many of them that they are not successful and lack the skills, or desire, needed to succeed. This subconscious anxiety is reflected in the quantitative findings regarding the associations between Learning Mathematics Anxiety and the learning environment scales.

When asked about the importance of feeling accepted by others in the class, and how that might affect their feelings regarding mathematics, opinions were equally divided. Some of the students said that it was a help to have friends or acquaintances in the class to turn to during difficult content. This allowed

them to feel at ease about asking questions to the instructor and obtaining help from their peers. Others said that how they felt about their peers wasn't important to them. As Samuel, a male 9th grader, said:

It really doesn't matter that much. Success depends on yourself. You have to have motivation to succeed. The ultimate choice falls on you.

This feeling of independence and self-determination was verbalised, but each of the students who answered this way also vocalised their desire to know the people in the class. Samuel went on to describe how his mathematics class felt to him in these words:

Most of the time [mathematics class] feels like I am hanging out with my friends. I'm having fun and I can block everything else out.

These feelings fit well into what we know about adolescents and their desire for peer approval. The need for young people to have friends and to be accepted causes anxiety in many ways and forms. Jon, a 9th grade male, summed it up this way:

In any class, you want to be liked. The more you are liked, the more you feel comfortable in the class. If you feel like an outcast, you just don't feel like showing up to class and aren't ready to learn. But, if you have friends, it can be more fun to learn each day and easier to learn and concentrate.

One other factor that came out clearly through the interviews and observation was the role of the teacher in creating an environment that is as free from anxiety as possible. Many of the students commented that the teacher's availability, verbal tone, and enthusiasm were keys to making the classroom a place where they felt that they could be successful. This was clearly found in the inductive analysis as Teacher Support was identified as a Tier III theme.

Many of the classrooms that displayed projects and work of which students were proud were places where the students verbalised low anxiety in the classroom. Prior to each test, one instructor handed out pencils on which

were printed the phrase "You know this stuff!" She also gave handshakes afterwards to students who had achieved higher than their previous class average. These actions were identified by students as important parts of decreasing the level of anxiety that was felt in the classroom. Through positive comments and actions, students were allowed to see themselves in a positive way and that feeling was reflected in their comfort level with the mathematics content.

Overall, the qualitative data obtained from the interviews seems to support some of the findings from the quantitative data. There did not seem to be much of a gender difference regarding the anxiety or attitudes towards mathematics that was brought out via the interviews. Many of the students interviewed vocalised that they do not perceive, nor wish to perceive, any form of investigation in their mathematics classroom. The students seem to be comfortable with the classroom being led by and focused on the instructor.

The interviews suggested that Student Cohesiveness has both a positive and negative impact on the class. Many students feel that it is important to have other classmates with whom they can associate in order to give and receive help with their work. Some students find relief in knowing that there are other students who can assist them as they study and prepare. Other students find that, when they help or teach others, it strengthens not only their knowledge of the subject area, but also their social standing.

But there are also many students who find the existence of a cohesive group in the classroom equally disturbing or disrupting. Students find themselves overly social with others whom they know extremely well and are pulled away from their academic pursuits. Still others are extremely fearful of making mistakes in front of their 'friends' and looking foolish. These people almost seem to wish that their mathematics experiences could take place in a vacuum, away from anyone else.

So, while Student Cohesiveness is a common theme in the interview data, there are inconsistent opinions as to its value and worth. While no clear answer came from the interview data, this issue seems to be on the minds of many students and therefore warrants further study.

These interviews seem to confirm that students view most of their mathematics instructors as 'normal', and that this attitude towards them seems somehow to influence the way in which they approach mathematics and the anxiety that it can cause. More than one person identified their teacher as the single most influential person in helping them to overcome whatever level of anxiety they were feeling in the mathematics classroom.

4.6 Conclusion

This study implemented both quantitative and qualitative methods in order to assess the validity and structure of the instruments used, to determine associations between the learning environment perceptions of high school students and their level of mathematics anxiety and attitudes towards mathematics, and differences between boys and girls with respect to these areas.

A sample of 745 students from four high schools in the Southern California area were used to gather quantitative data, while a sub-sample of 18 students were interviewed to collect the qualitative data. Quantitative data were collected using the What Is Happening In this Class? learning environment instrument, the Test of Mathematics-Related Attitudes, and the Revised Mathematics Anxiety Ratings Scale, which identifies the level of mathematics anxiety in two different areas.

Factor, reliability, and validity analyses were performed for each instrument in order to identify the usefulness in the results obtained from them. Statistical testing was used to determine gender differences using both within-class gender means and individual students as the units of analysis. Finally,

simple correlation and multiple regression methods were analysed in order to identify possible associations between the learning environment scales and both anxiety and attitudes.

The factor analyses revealed that the instruments used in this study are factorially valid as they measure the various components of the learning environment, mathematics anxiety, and attitudes towards mathematics. The WIHIC scales account for nearly 60% of the total variance, while Cronbach alpha reliability coefficients for each scale all exceed .75 for both the individual and class mean units of analysis. Discriminant validity (the mean correlation of a scale with the other scales) is less than .51 for both units of analysis. ANOVA revealed that all but two WIHIC scales are able to differentiate between classrooms.

The factor analysis for TOMRA showed that only two scales, Enjoyment of Mathematics Lessons and Normality of Mathematicians, should be retained for further use in this research. Those two scales account for almost 30% of the total variation and possess Cronbach alpha reliability coefficients that exceed .79 when using either unit of analysis (individual and class mean). The mean correlation score, as indicators of discriminant validity, are moderate, but acceptable.

Factor and reliability analysis for the RMARS showed strong results consistent with previous uses of this instrument. The two scales of Learning Mathematics Anxiety and Mathematics Evaluation Anxiety account for over 54% of the total variation of the instrument and Cronbach alpha reliability coefficients all exceed .91 for both units of analysis. Likewise, the mean correlation validity scores for the two scales of the RMARS indicate acceptable discriminant validity..

Investigation of gender differences in learning environment, attitude towards mathematics, and mathematics anxiety scales involved both the within-class gender mean and the individual student as the units of analysis. These analyses enabled us to see that there are differences in the way in which males

and females perceive the learning environment in mathematics classrooms. Females seem to perceive that there is more of a social aspect to the classroom, that they are more motivated to succeed in the classroom and, surprisingly, that they are being treated more fairly than the males by the teachers. While this does replicate previous learning environment research, it is different from some findings from past mathematics education research.

Correlation and multiple regression analyses seem to suggest that, while the learning environment does not play a role in the level of the anxiety caused by evaluation and testing, it does play a significant role in the level of anxiety felt during the classroom instruction. The areas of Student Cohesiveness and Task Orientation were significantly related to anxiety in both types of analyses.

The analyses also seem to suggest that the level of enjoyment that a student feels is directly related to the learning environment, especially Investigation, Task Orientation, and Cooperation. The Normality of Mathematicians scores were influenced by the level of Equity that a student perceives, signifying the importance of the teacher as a supporter and encourager in the classroom situation.

Finally, qualitative data from the interviews confirmed the importance of the learning environment in the level of mathematics anxiety that a student perceives and the attitude towards mathematics that a student holds. Especially noteworthy is confirmation of the importance of Teacher Support and Student Cohesiveness in reducing anxiety found via these interviews. This replicates previous research on the influence of the learning environment on outcomes (Aldridge & Fraser, 2000; Kim, Fisher, & Fraser, 2000; Margianti, Fraser, & Aldridge, 2002).

The significance of these findings is discussed in the next chapter, as well as some possible biases or limitations associated with the data collection, analyses, or interpretation.

Chapter 5

Summary, Conclusions, and Recommendations

5.1 Introduction

While data collection and analyses are vital elements of sound research, it is in the application of research results where the true changes can take place. Great care must be taken to determine the appropriate application of the results so that they can achieve the greatest impact in the area being studied. This is not a new phenomenon. In 1911, Alfred Whitehead said the following:

But in truth, with more complicated instances there is no more common error than to assume that, because prolonged and accurate mathematical calculations have been made, the application of the result to some fact of nature is absolutely certain.
(p. 27)

This chapter begins with a summary of my thesis and the research objectives which guided my study (Section 5.2). Specific findings and conclusions from the data analyses are discussed in Section 5.3. Section 5.4 reviews the limitations and potential biases associated with my study, while Section 5.5 identifies the various implications of my study for research and teaching. Recommendations for further research follow in Section 5.6, and some concluding remarks are located in Section 5.7.

5.2 Summary of Thesis

My study represents the first time that the research areas involving learning environments, attitudes towards mathematics, and mathematics anxiety have been simultaneously investigated. Four overriding objectives governed my study:

1. To provide reliability and validity data for measures of mathematics anxiety, attitudes and classroom learning environment when used with high school students in Southern California.
2. To investigate gender differences in mathematics anxiety, attitudes and perceptions of learning environment using within-class and between-student comparisons.
3. To determine if there are associations between classroom learning environment dimensions and the level of mathematics anxiety and attitudes.
4. To explain why certain associations exist between mathematics anxiety and attitudes and learning environment by using qualitative research methods.

Chapter 1 of the thesis gives a concise statement of the problem which is being investigated in my research, namely, "How does the classroom learning environment affect high school students' feelings of mathematics anxiety and their attitudes towards mathematics?" Implications of my research from a theoretical, methodological, and practical position are also discussed in this initial chapter.

The second chapter contains a review of the literature regarding the three main areas of study for my research: classroom learning environments, mathematics anxiety, and attitudes towards mathematics. The history and foundations of classroom learning environment research, the various instruments used in this field, and the What Is Happening In this Class? learning environment instrument used in my study are also included in this chapter. The literature describing the fields of mathematics anxiety and attitudes towards mathematics concludes Chapter 2.

Chapter 3 describes the methodology used in my study, the demographics of the sample that participated, and the details of the instruments used to collect data. My study focused on combining quantitative and qualitative data in order to determine associations between classroom

learning environment and mathematics anxiety and attitudes towards mathematics scales. These associations were determined after factor analysis, discriminant validity, and reliability testing was performed on each instrument in order to determine its suitability with the sample used in my study.

Quantitative data were gathered from 745 students in four high schools located in Southern California. These students were in 34 mathematics classes and represented students from Grades 9 through 12. With nearly even representation of the genders and grade levels, this sample is a good representation of typical students in Southern California mathematics classrooms.

Quantitative data were collected via three instruments. The What Is Happening In this Class? (WIHIC; Fraser, McRobbie, & Fisher, 1996) learning environment instrument measured students' perceptions of seven psychosocial learning environment areas: Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, and Equity. There are 56 total items in the WIHIC, with each scale having 8 questions.

In order to measure attitudes towards mathematics, the Test of Mathematics-Related Attitudes (TOMRA) was created from a similar science-based instrument known as the Test of Science-Related Attitudes (TOSRA; Fraser, 1981). The original TOMRA used in my study included four scales with 10 questions each. These scales assess Enjoyment of Mathematics Lessons, Adoption of Mathematics Attitudes, Attitudes Towards Mathematics, and Normality of Mathematicians.

The instrument used to measure two factors of mathematics anxiety used in my study was an updated version of the Revised Mathematics Anxiety

Ratings Scale (RMARS; Plake & Parker, 1982). This instrument measures perceptions of mathematics anxiety in two areas: Learning Mathematics Anxiety and Mathematics Evaluation Anxiety. There are 24 questions altogether in the RMARS, with 16 of them assessing the Learning Mathematics Anxiety scale.

The data from the three instruments were first analysed for factor structure, reliability, and discriminant validity. Factor analysis was carried out using the principal component method with Kaiser varimax rotation. Internal consistency reliability was determined by using the Cronbach alpha coefficient, while discriminant validity was quantified by using the mean correlation between scales. For the classroom learning environment instrument, the η^2 statistic from ANOVA was used to determine whether the WIHIC could differentiate between various classrooms.

Once the instruments had been shown to be reliable and valid, the data were analysed to investigate gender differences in the various learning environment, attitude, and mathematics anxiety scales. Within-class means were initially used as the unit of analysis with paired *t*-tests to identify statistically significant differences between the genders. A modified Bonferroni procedure was implemented to reduce the level of Type I error associated with multiple comparisons testing. Effect sizes were also used to estimate the magnitude of the differences without the influence of sample size.

The individual students were also used as a unit of analysis in a Multivariate Analysis of Variance (MANOVA) to further explore possible gender differences in the various scales. A possible interaction between gender and grade was tested and found to not be present. Gender differences for each individual dependent variable were ascertained by the interpreting the univariate ANOVA.

Associations between the classroom learning environment factors and attitude and anxiety factors were explored by using simple correlation techniques and multiple regression models. Using the learning environment scales as the independent variables, I investigated if these scales had significant statistical relationships with the various anxiety and attitude scales when all the learning environment scales were mutually controlled.

Qualitative data were collected through interviews with 18 students, drawn from the sample because of their perceived level of mathematics anxiety as quantified on the RMARS. Nine students identified themselves as having extremely low anxiety, while the other nine considered themselves as highly anxious with regards to mathematics based on the RMARS scores. These interviews took place after the survey instruments were completed and were used to help to corroborate or refute findings from the quantitative data, as well as to uncover any other issues that the instruments did not examine.

Inductive interview methods were used to categorise and identify major themes in the qualitative data and to compare with the findings obtained from the quantitative data. Using quotations as the unit of analysis, common themes were paired together to identify first-level themes. These common themes were then grouped together again to identify overall points of emphasis until the major themes of the interviews were identified and categorised.

5.3 Findings and Conclusions

The findings of my study can be divided into four areas, each relating to the research objectives serving as the foundation of the study. Each of the following subsections deals with the results of the data analyses related to the objectives and is a summary of the results reported in Chapter 4.

Section 5.3.1 focuses on the factor analysis, internal consistency reliability, and discriminant validity results for each of the instruments used in my study. Section 5.3.2 summarises the findings from the analyses dealing with gender differences. The next section, Section 5.3.3, reviews the findings for the correlation and multiple regression analyses which explored associations between classroom learning environment and anxiety/attitudes scales. The final section (Section 5.3.4) summarises the findings of the qualitative data analyses and compares them with the quantitative data findings.

5.3.1 *Factor Structure, Reliability, and Validity of Instruments*

The first findings from my study were related to the factor, discriminant validity, and reliability analyses for each of the three instruments used to gather data. Factor loadings for individual questions were determined via principal component factor analysis involving Kaiser varimax rotation. Internal consistency reliability was determined using Cronbach's alpha coefficient. Discriminant validity was calculated using the mean correlation between scales. Both of the reliability and validity measures were calculated using both the individual and the class mean as the units of analysis. Also, for the classroom learning environment instrument, the η^2 statistic from the ANOVA was used as a measure of the ability of each scale to differentiate between student perceptions in different classrooms.

The factor analysis for the WIHIC found that the *a priori* seven-scale structure applied to my study's data with nearly all items having a factor loading over .40 on its own scale, but less than .40 with all other scales. Two questions from the Student Cohesiveness scale did not meet this factor loading threshold and were not included in the rest of the data analyses. The total percentage of variance accounted for by the seven scales was nearly 60% and all scales had an eigenvalue of greater than 1.

The Cronbach alpha coefficient values for the WIHIC scales ranged from .82 to .91 when the individual was used as the unit of analysis, and from .75 to .96 when the class mean was used as the unit of analysis. These coefficients reflect a high level of internal consistency for the WIHIC. The mean correlation between scales, used to determine discriminant validity, ranged from .30 to .44 at the individual level, and from .35 to .54 at the class mean level. This confirms that there is a reasonable level of independence among the scales.

The ability to differentiate between classrooms is an important characteristic of any classroom learning environment scale. In order to quantify this for the WIHIC, the η^2 statistic from ANOVA was used. This statistic ranged from .05 to .12 for the seven scales of the WIHIC, with statistically significant differences found for all the scales except Student Cohesiveness and Investigation. Because of the relatively low standard deviations of the scores in these two scales, it was determined that the result of non-significance was not a problem with regards to the ability of the instrument to differentiate between classrooms.

The results for the attitude instrument (TOMRA) revealed through factor analysis that only two of the original four scales should be retained for use in my study. Factor analysis showed that the factor loadings for 9 of the 10 questions in the Enjoyment of Mathematics Lessons scale and for all 10 questions in the Normality of Mathematicians scale were over .40 on their own scales and less than .40 on all other scales. The two scales that did not survive the factor analysis, Adoption of Mathematics Attitudes and Attitudes Towards Mathematics, were not used in any of the subsequent data analysis. Because of this, only 30% of the total variance in the instrument was attributable to the two remaining scales. Each of the attitude factors, however, had an eigenvalue greater than 3.

The Cronbach alpha coefficients for the remaining two attitude scales were .92 and .79 at the individual level, and .95 and .90 at the class mean level. The mean correlation between scales was .59 using the individual as the unit of analysis and .50 using the class mean. Again, these values reflect that the two remaining scales possess high internal consistency and modest independence. Even with the potential difficulties involving the factor analysis, the remaining scales are strong measures of the areas that they explore.

The findings for the factor analysis of the RMARS confirmed the two-factor *a priori* scale structure consisting of anxiety related to the learning of mathematics and the evaluation of mathematics. These two factors, Learning Mathematics Anxiety and Mathematics Evaluation Anxiety, were both found to be very strong through the factor analysis. All 16 questions in the Learning Mathematics Anxiety scale and all 8 items in the Mathematics Evaluation Anxiety scale were found to have factor loadings greater than .40 on their own scale only. The two scales of the RMARS account for nearly 55% of the total variance in the instrument and have eigenvalues greater than 2.

Validity and reliability scores for the RMARS were also very strong. Cronbach's alpha coefficients were .92 and .91 for the individual level and .96 and .94 for the class mean level. The mean correlation between the scales was .33 at the individual level and .58 at the class mean level. These values are indicators of the suitability of the RMARS in measuring mathematics anxiety.

5.3.2 *Gender Difference Findings*

Once the three instruments had been shown to be reliable and valid for the high school mathematics classrooms of Southern California, gender differences were determined for each of the scales measuring learning

environment, attitudes towards mathematics, and mathematics anxiety. Two levels of analysis were used when investigating possible differences between males and females. Two different units of analysis were used to determine gender differences. The within-class gender mean, or the average response for each item when gender and class membership are accounted for, was used first. Next, the individual student was used as the unit of analysis.

The within-class gender mean was employed as the unit of analysis with paired-sample *t*-test that also incorporated a modified Bonferroni procedure to determine statistically significant differences. While no statistically significant gender differences were detected for either of the attitude or anxiety scales, four scales were found to have significant gender differences in the area of classroom learning environments. Females were found to have significantly higher perceptions of the classroom in the areas of Equity, Student Cohesiveness, Task Orientation, and Cooperation. The effect sizes for the statistically significant gender differences ranged from .96 to .56 standard deviations.

These within-class gender differences tend to reflect two main focal points in which the differences are related. First, these findings emphasize social and motivational differences between males and females in the high school setting. It would appear from these results that building a positive social structure in the classroom is more important among females in these mathematics classrooms. Implementing cooperative learning techniques and supporting a sense of cohesiveness in the classroom appear to be of vital importance to the females in this sample.

The second focal point of these within-class gender difference results is the perceived leveling of equity in the high school mathematics classroom. This has been an issue in mathematics education researchers for the past 20 years, with researchers agreeing that females usually perceive less equity and

fairness in the mathematics classroom (Campbell & Evans, 1997; Hembree, 1990; Levine, 1995; Meece, 1981). In my study, the data suggest that the females felt that there was more equity in their classroom situations than the boys perceived. This result could suggest that the efforts of mathematics educators over the past decade in emphasizing the need for equity in the classroom are beginning to pay off. This also could reflect the inherent difference between the way the concept of equity is used in mathematics education and classroom learning environment research.

Gender differences were also explored using the individual student as the unit of analysis. Using a MANOVA, gender differences were determined for each of the scales of the learning environment, attitude, and anxiety instruments. Each of the four learning environment scales (Student Cohesiveness, Equity, Cooperation, and Task Orientation) which were identified as having significant gender differences using the within-class analysis also yielded statistically significant gender differences using the individual student as the level of analysis. Also, a significant gender difference was identified for the area of Teacher Support, with females once again having a more positive perspective than males. These results are consistent with past learning environment research on gender differences (Adolphe, Fraser, & Aldridge, 2003; Margianti, Fraser, & Aldridge, 2002; Moss & Fraser, 2001).

While no gender differences were detected in the attitude scales using the individual as the unit of analysis, significant differences were found for both of the mathematics anxiety scales. These additional differences, not found in the within-class gender analysis, could be attributed to possible Type II errors during the use of a modified Bonferroni procedure in the within-class gender mean testing. This analysis revealed that females in the sample are more anxious about the evaluation of the mathematics content, while males

are more anxious about the process of learning mathematics through classroom instruction.

5.3.3 *Findings of Associations Between Learning Environments with Attitudes and Anxiety*

Associations were explored between the learning environment factors and each of the attitude/anxiety scales. Simple correlation and multiple regression analyses were conducted in order to determine these associations.

No statistically significant relationships were found between the learning environment scales and Mathematics Evaluation Anxiety in either the correlation or multiple regression analyses. This is not surprising as the testing and evaluating of mathematics is seemingly independent from the learning environment.

The associations found between the learning environment scales and Learning Mathematics Anxiety include significant, negative, and independent relationships with Student Cohesiveness, Task Orientation and, at times, Cooperation, as well as significant, positive, and independent influences from Investigation. These findings seem to suggest that the interpersonal relationships that a student feels in the classroom can affect the way that they feel about the subject area as well.

While nearly all the learning environment scales were correlated with the Enjoyment of Mathematics Lessons attitude scale, multiple regression analysis revealed that Investigation and Task Orientation had significant, positive, and independent associations with student enjoyment during lessons. Also, Cooperation was found to have a significant, negative, and independent influence on the Enjoyment of Mathematics Lessons. This seems

to confirm that the learning environment does play a role in the level of enjoyment that a student experiences in the mathematics classroom.

The final area of investigation for associations was between the Normality of Mathematicians scale and the learning environment factors. Two areas provided significant relationships when all the learning environment scales were mutually controlled. Equity was found to have a positive and independent association with Normality of Mathematicians and Involvement was found to have a significant, negative, and independent association. Also, Equity, Teachers Support, and Task Orientation were found to have significant simple correlations with the Normality of Mathematicians factor. These results reflect a general consistency with prior research regarding outcome-environment associations (Aldridge & Fraser, 2000; Khine, 2001; Margianti, Fraser, & Aldridge, 2002).

5.3.4 *Qualitative Data Findings*

The qualitative data analysis confirmed that many of the findings from the quantitative data and also identified another area of influence on the mathematics anxiety of high school students. Through the use of Miles and Huberman's (1984) inductive method of analysis involving the combining of common themes found in the data, the influences of Teacher Support, Student Cohesiveness, and Cooperation on the level of mathematics anxiety was corroborated. These areas, as well as the level of anxiety associate with testing and the learning of mathematics, were brought forth by interview quotes as being important issues facing high school mathematics students.

The new area which was uncovered in the interviews was the influence of the structure of the mathematical content on mathematics anxiety. The way in which mathematics builds upon itself and the complexity of mathematics were seen as important factors in the mathematics classroom for many

students who were interviewed. While not a specific part of the classroom learning environment per se, it is an inherent part of the mathematics classrooms and therefore weaves its way through the classroom structure and attitudes which students bring to a mathematics class.

5.4 Limitations and Biases of Study

While efforts were made to ensure that my study's data gathering, analysis, and findings are free from biases or errors, certain inherent limitations and biases still could exist. Research can never be free of limitations and biases, especially when working with human subjects, but every effort must be made to acknowledge their existence and minimize their effects.

The first limitations on my research involve the sample and the gathering of data. The size of the sample, while large enough to perform the desired analyses, would need to be larger in order to more clearly define the relationships between the scales and avoid the multicollinearity that exists in my study. The demographics of the sample could also be improved as well. While my sample had a fairly equal split between grade levels and genders, the ethnic make-up of my sample does not necessarily reflect that of the general population in Southern California. While the percentage of Hispanic, Caucasian, and Asian students resembled the general population, the number of African-American students in my study was lower than what is customary in Southern Californian high schools.

The sample is not a true random sample as only classrooms where teachers were willing to participate in my study were used at each high school. This also applies to the students as well. Only those students who had parental consent were used in my study. Surprisingly, many parents chose not to have their students participate and therefore were eliminated from the

data gathering. A true random sample is always preferred in data gathering, but realistically this is not possible in nearly all educational research studies due to the necessity for parental consent and approval of the cooperating teachers.

Another possible additional limitation of my research involves the method by which the data were gathered. An initial letter was sent to the principals of the participating schools to explain the purpose and plans for my research. A copy of this letter is found in Appendix F. While the exact questionnaires were given to each school and thereby distributed to the classroom teachers, I was not present in every classroom during the answering of the surveys. Teachers had freedom to distribute these in any order that they chose, and the length of time allocated for students to complete the questionnaires was at the discretion of the instructor. While I do not believe that any major errors or discrepancies occurred because of these sampling techniques, they do pose possible limitations or could have created potential biases at some level.

The qualitative data were also subject to biases and limitations as well. Patton (1990) states that the interpretation of interview data can never be free from the personal interpretations and biases of the researcher conducting the interview or analysing the data. While every effort was made to view the data through the eyes of the subject being interviewed, these biases still exist. The interview protocol and scripting of the questions was used in an attempt to diminish the effects of the researcher on the analysis.

5.5 Implications of This Study

The results of my study have methodological, theoretical, and practical implications for researchers and instructors alike. English and her associates

(2002) support the belief that mathematics education research can serve both camps equally well:

The interplay between the research process and classroom practice is mutually supportive, and conclusions drawn from such research have implication for instructional theory and practice, cognitive functioning of collective groups and individuals, and social and cultural perspectives in the classroom (p. 795).

This has been the goal of my research since its inception. My research should not only have connections to sound methods and techniques in order to identify theoretical relationships and associations, but it should also serve a practical value to those who are teaching and learning inside the classroom.

The results of my study should be used by fellow researchers to obtain another component of the classroom environment, especially that of the mathematics classroom. From my study, it is clear that elements of the environment can play a role in the reduction of anxiety and the building of positive attitudes towards mathematics. These elements should be considered with other research to determine the most important focal points for instructors when building their classroom environment.

Researchers can also conclude from my study that the three instruments used are appropriate for use in the mathematics classrooms of high schools in Southern California. This methodological implication will enable other researchers to carry out valuable studies with regards to the classroom learning environment, mathematics anxiety, or attitudes towards mathematics or some combination thereof. These instruments have been used worldwide in some cases, and therefore allow researchers in Southern California to compare with classroom situations in many other cultures and countries.

These instruments could also be used by classroom teachers in action research situations (Sinclair & Fraser, 2002; Yarrow, Millwater, & Fraser, 1997). These efforts in action research are designed to improve the classroom learning environment in the teacher's own classroom. The instruments used in my study would be helpful for teachers to use for identifying areas of the learning environment that need improvement or to examine potential mathematics anxiety or attitude problems of their students.

There are practical applications of my research for the mathematics classroom teacher also. The instructional methods used by a teacher and the manipulation of the classroom environment are two areas that can be affected by my study.

It is clear from the results of my study that the mathematics classroom has a tension surrounding the use of investigation when learning new topics. While the quantitative data show that the use of investigation reduces the level of anxiety related to learning mathematics and increases the enjoyment of the mathematics lessons, there is also evidence from the within-class gender analysis and qualitative data that many students are not comfortable with investigating mathematics topics or have not had many opportunities to do so. This leaves the instructor with a decision to make: Should they decide to implement an investigative approach to the learning of mathematics or not?

From my study, the recommendation that I would make is that the use of investigation is appropriate and important, but that certain precautions should be made by the instructor when using it. First, it should be used sparingly at first, with the intent of getting students comfortable with the process and implementation of the methods. This could mean that the content initially investigated is fairly straightforward and does not deal with detailed or difficult concepts.

Secondly, the use of investigation must be placed within the context of cooperation and the building of student cohesiveness. The investigation itself does not seem as important to students as the result of building a community of learning and the relationships between students that can be fostered. This seemingly enables the students to approach the difficulty of the mathematics content with a sense that they are not alone in this endeavor, which also reduces the anxiety level that the students feel.

The second area of influence that my study can have in the mathematics classroom is in the manipulation and use of the environment that teachers build in the classroom. From my study, this was identified in two main areas. First, the role of the teacher in setting the tone and the ability of the instructor to diminish anxiety was fairly pronounced. Second, the importance of the overall level of student cohesiveness in a classroom was clearly established through the student responses.

The role of the instructor in setting an enjoyable and affirming classroom environment was found in multiple places in the data of my study, especially through the qualitative data. The instructor's level of excitement towards mathematics, the students' perceived openness for questions and ability to help, and the energy that was brought into the lessons were all seen as important qualities which enhance learning and reduce anxiety. While some of these qualities reflect highly-gifted and experienced teachers, there are many others that are connected more to the climate that instructors set as opposed to just their personality style.

Also, the level of cohesiveness felt by the students in the classroom is an important quality for reducing anxiety in the mathematics classroom and raising the level of enjoyment of the mathematics lessons. This feeling of community and togetherness was repeated in a variety of fashions during the data analyses and is certainly valued by the students participating in my

study. Many students stated that they had a desire to be in a classroom where the instructor incorporated into the classroom the sense of students helping each other and valued the feeling of community that this cohesiveness brings.

5.6 Recommendations for Further Research

One of the underlying purposes of research is that it influences and motivates further research. There are a number of further research opportunities that grow out of my study and should be examined in the future.

One of the first studies that could be undertaken would involve replication of my research to add greater confidence in my findings. This could be done with a larger sample involving more schools in the Southern California area. Using the same three instruments, associations and relationships between learning environment, mathematics anxiety, and attitudes towards mathematics could be investigated. Also, extending this study to a larger scope, even one of an international scale, is appropriate and could yield interesting comparisons.

A confirmatory factor analysis should be performed for the WIHIC, RMARS and TOMRA instruments should in order to further investigate the structure, validity, and reliability of the anxiety and attitude surveys. Dorman (2003) has already successfully done this with the WIHIC learning environment instrument. While the results of the TOMRA in my study were acceptable, there is ample room to clarify the use of this instrument and its impact on research into attitudes towards mathematics and mathematicians. Likewise, the RMARS instrument, after 20 years of use, still would benefit from this process.

Another area of research that stems from my study would be an investigation into the relationship between the perceived normality of mathematicians, or mathematics teachers, and the level of mathematics anxiety that a student feels. If a student identifies more with their instructor, does that change the level of anxiety that a person feels towards mathematics? While my study investigated associations between the students' attitudes about the normality of their teacher and the classroom learning environment, it did not look into possible relationships between anxiety and the attitudes about the normality of the teacher.

There are other areas of study that would benefit the educational community and impact the mathematics classroom. The role of the learning environment in a mathematics classroom to provide opportunities for the academic success of individual students would enable teachers to see the practical importance of developing enriching and supportive environments. Also, the level of enjoyment during mathematics classes could be related to the academic success of students as well. Finally, the role of humor in the classroom environment and its impact on the attitudes and anxiety of students is a forgotten component of the classroom dynamic and should be analysed in the future as well.

5.7 Concluding Remarks

The study of classroom environments has made its mark on the methods and style of teachers worldwide. Likewise, the study of mathematics anxiety has influenced the content and teaching of mathematics for many years. These two research areas, coupled with the attitudes of students towards mathematics, offer the potential for a rich and dynamic area of study. It is my hope that, through the research presented here, information and ideas can be shared that will make the mathematics classroom a place of success and confidence for students and not of fear and dread.

References

- Adolphe, F.S.G., Fraser, B.J., & Aldridge, J.M. (2003, January). *A cross-national study of classroom environment and attitudes among junior secondary science students in Australia and Indonesia*. Paper presented at the Third International Science, Mathematics and Technology Education Conference, East London, South Africa.
- Aksu, M. (1991). A longitudinal study on attitudes towards mathematics by department and sex at the university level. *School Science and Mathematics, 91*, 185-193.
- Aldridge, J.M., & Fraser, B.J. (2000). A cross-cultural study of classroom learning environments in Australia and Taiwan. *Learning Environments Research, 3*, 101-134.
- Aldridge, J.M., Fraser, B.J., & Huang, T.-C.I. (1999). Investigating classroom environments in Taiwan and Australia with multiple research methods. *Journal of Educational Research, 93*, 48-62.
- Aldridge, J.M., Fraser, B.J., Taylor, P.C., & Chen, C.-C. (2000). Constructivist learning environments in a cross-national study in Taiwan and Australia. *International Journal of Science Education, 22*, 37-55.
- Alexander, L., & Martray, C. (1989). The development of an abbreviated version of the mathematics anxiety rating scale. *Measurement and Evaluation in Counseling and Development, 22*, 143-150.

- Allen, D., & Fraser, B.J. (2002, April). *Parent and student perceptions of the classroom learning environment and its influence on student outcomes*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.
- Asghar, M., & Fraser, B. (1995). Classroom environment and attitudes to science in Brunei Darussalam. *Journal of Science and Mathematics Education in Southeast Asia, XVIII*(2), 41-47.
- Barnette, J.J. (2000). Effects of stem and Likert response option reversals on survey internal consistency: If you feel the need, there is a better alternative to using negatively worded stems. *Educational and Psychological Measurement, 60*, 361-370.
- Blum, T.L., & Staats, W.J. (1999, November). *The assessment of cognitive skills for computer science education*. Paper presented at the annual Frontiers in Education Conference of the American Society of Engineering Education, San Juan, Puerto Rico.
- Brown, F.S. (1996, April). *The effect of an inquiry-oriented environmental science course on preservice elementary teachers' attitudes about science*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, St. Louis, MO.
- Buckley, P.A., & Ribordy, S.C. (1982, May). *Mathematics anxiety and the effects of evaluative instructions on math performance*. Paper presented at the Midwestern Psychological Association, Minneapolis, MN.
- Burden, R., & Fraser, B.J. (1993). Use of classroom environment assessments in school psychology: A British perspective. *Psychology in the Schools, 30*, 232-240.

- Butler, M.R., & McNertney, E.M. (1991). Estimating educational production functions: The problem of multicollinearity. *Social Science Journal, 4*, 489-499.
- Butty, J.A. (2001). Teacher instruction, student attitudes, and mathematics performance among 10th and 12th grade black and Hispanic students. *The Journal of Negro Education, 70*, 19-37.
- Campbell, K.T., & Evans, C. (1997). Gender issues in the classroom: A comparison of mathematics anxiety. *Education, 117*, 332-338.
- Capraro, M.M., Capraro, R.M., & Henson, R.K. (2001). Measurement error of scores on the mathematics anxiety rating scale across studies. *Educational and Psychological Measurement, 61*, 373-386.
- Carver, R.P. (1978). The case against statistical significance testing. *Harvard Educational Review, 48*, 378-399.
- Chua, S.L., Wong, A.F.L., & Chen, D.-T. (2001, December). *Validation of the Chinese Language Classroom Environment Inventory (CLCEI) for use in Singapore secondary schools*. Paper presented at the annual conference of the Australian Association for Research in Education, Fremantle, Western Australia.
- Chouinard, R., Vezeau, C., Bouffard, T., & Jenkins, B. (1999). Gender differences in the development of mathematics attitudes. *Journal of Research and Development in Education, 32*, 184-192.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

- Cohen, L., Manion, L., & Morrison, K. (2001). *Research methods in education* (5th ed.). New York: RoutledgeFalmer.
- Creton, H., Hermans, J., & Wubbels, T. (1990). Improving interpersonal teacher behaviour in the classroom: A systems communication perspective. *South Pacific Journal of Teacher Education*, 18, 85-94.
- Deeds, D.G., Wood, M.D., Callen, B.W., & Allen, C.S. (1999). Contemporary student attitudes about mathematics, science, and technology. *Journal of College Science Teaching*, 2, 86-92.
- Denzin, N.K., & Lincoln, Y.S. (2000). The discipline and practice of qualitative research. In N.K. Denzin & Y.S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed.) (pp. 1-28). Thousand Oaks, CA: Sage Publications.
- Dorman, J.P. (2001). Associations between classroom environment and academic efficacy. *Learning Environments Research*, 4, 243-257.
- Dorman, J.P. (2003). Cross-national validation of the What Is Happening In This Class? (WIHIC) questionnaire using confirmatory factory analysis. *Learning Environments Research*, 6, 231-245.
- Dungan, J.F., & Thurlow, G.R. (1989). Students' attitudes towards mathematics: A review of the literature. *Australian Mathematics Teacher*, 45, 8-11.
- Ellis, H.C., Varner, L.J., & Becker, A.S. (1993). Cognition and emotion: Theories, implications, and educational applications. In L.A. Penner, G.M. Batsche, H.M. Knoff, & D.L. Nelson (Eds.), *The challenge in mathematics and science education: Psychology's response* (pp. 83-111). Washington, DC: American Psychological Association.

- English, L.D. (2002). Priority themes and issues in international research in mathematics education. In L.D. English (Ed.), *Handbook of international research in mathematics education* (pp. 3-16). Mahwah, NJ: Lawrence Erlbaum Associates.
- English, L.D., Jones, G.A., Lesh, R.A., Tirosh, D., & Bussi, M.B. (2002). Future issues and directions in international mathematics education research. In L.D. English (Ed.), *Handbook of international research in mathematics education* (pp. 787-812). Mahwah, NJ: Lawrence Erlbaum Associates.
- Fennema, E., & Sherman, J.A. (1976). Fennema-Sherman Mathematics Attitudes Scales: Instruments designed to measure attitudes towards the learning of mathematics by males and females. *JSAS Catalog of Selected Documents in Psychology*, 6(1), 3b.
- Fisher, D.L., & Fraser, B.J. (1983). A comparison of actual and preferred classroom environment as perceived by science teachers and students. *Journal of Research in Science Teaching*, 20, 55-61.
- Fisher, D., Harrison, A., Hofstein, A., & Henderson, D. (1998). Laboratory learning environments and practical tasks in senior secondary sciences classes. *Research in Science Education*, 28, 353-363.
- Fisher, D.L., & Rickards, T.W.J. (1998, April). *A comparison of teacher-student interpersonal behavior in secondary science classes in USA, Singapore and Australia*. Paper presented at the annual meeting of the National Science Teachers Association, Las Vegas, NV.

- Fisher, D., Rickards, T., & Fraser, B. (1996). Assessing teacher-student interpersonal relationships in science classes. *Australian Science Teachers Journal*, 42, 28-33.
- Fisher, D., Rickards, T., & Newby, M. (2001, December). *A multi-level model of classroom interactions using teacher and student perceptions*. Paper presented at the annual meeting of the Australian Association for Research in Education, Fremantle, Australia.
- Fontana, A., & Frey, J.H. (2000). The Interview: From structured questions to negotiated text. In N.K. Denzin & Y.S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed.) (pp. 645-672). Thousand Oaks, CA: Sage Publications.
- Fraser, B.J. (1981). *Test of Science-Related Attitudes*. Melbourne, Australia: The Australian Council for Educational Research Limited.
- Fraser, B.J. (1990). *Individualised classroom environment questionnaire*. Melbourne, Australia: The Australian Council for Educational Research Limited.
- Fraser, B.J. (1994). Research on classroom and school climate. In D. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 493-541). New York: Macmillan.
- Fraser, B.J. (1998a). The birth of a new journal: Editor's introduction. *Learning Environments Research*, 1, 1-5.
- Fraser, B.J. (1998b). Science learning environments: Assessment, effects and determinants. In B.J. Fraser & K.G. Tobin (Eds.), *International handbook of science education* (pp. 527-564). Dordrecht, The Netherlands: Kluwer.

- Fraser, B.J. (1998c). Classroom environment instruments: Development, validity and applications. *Learning Environments Research*, 1, 7-33.
- Fraser, B.J. (2002). Learning environments research: Yesterday, today and tomorrow. In S.W. Goh & M.S. Khine (Eds.), *Studies in educational learning environments: An international perspective* (pp. 1-26). Singapore: World Scientific.
- Fraser, B.J., Anderson, G.J., & Walberg, H.J. (1982). *Assessment of learning environments: Manual for Learning Environment Inventory (LEI) and My Class Inventory (MCI)* (3rd version). Perth, Australia: Western Australian Institute of Technology.
- Fraser, B.J., & Chionh, Y.H. (2000, April). *Classroom environments, self esteem, achievement, and attitudes in geography and mathematics in Singapore*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.
- Fraser, B.J., Giddings, G.J., & McRobbie, C.J. (1995). Evolution and validation of a personal form of an instrument for assessing science laboratory classroom environments. *Journal of Research in Science Teaching*, 32, 399-422.
- Fraser, B.J., McRobbie, C.J., & Fisher, D.L. (1996, April). *Development, validation and use of personal and class forms of a new classroom environment instrument*. Paper presented at the annual meeting of the American Educational Research Association, New York.
- Fraser, B.J., & Tobin, K. (1991). Combining qualitative and quantitative methods in classroom environment research. In B.J. Fraser & H.J. Walberg (Eds.), *Educational environments: Evaluation, antecedents and consequences* (pp. 271-291). London: Pergamon Press.

- Fraser, B.J., & Treagust, D.F. (1986). Validity and use of an instrument for assessing classroom psychosocial environment in higher education. *Higher Education, 15*, 37-57.
- Fraser, B.J., & Walberg, H.J. (Eds.). (1991). *Educational environments: Evaluation, antecedents and consequences*. London: Pergamon.
- Furner, J.M., & Duffy, M.L. (2002). Equity for all students in the new millennium: Disabling math anxiety. *Intervention in School and Clinic, 38*, p. 67-74.
- Goh, S.C., & Khine, M.S. (Eds.). (2002). *Studies in educational learning environments: An international perspective*. Singapore: World Scientific.
- Gray, P., Aldridge, J.M., & Fraser, B.J. (2003, April). *The learning environment associated with an innovative program for at-risk students*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.
- Grouws, D.A., & Cramer, K. (1989). Teaching practices and student affect in problem-solving lessons of select junior high mathematics teachers. In D.B. McLeod & V.M. Adams (Eds.), *Affect and mathematical problem solving: A new perspective* (pp. 149-161). New York: Springer-Verlag.
- Hannafin, M.J. (1985). Review of Mathematics Anxiety Ratings Scale. In J.V. Mitchell, Jr. (Ed.), *The ninth mental measurements yearbook* (pp. 909-911). Lincoln, NE: Buros Institute of Mental Measurements.
- Hannula, M.S. (2002). Attitude towards mathematics: Emotion, expectations and values. *Educational Studies in Mathematics, 1*, 25-46.

- Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education*, 21, 33-46.
- Henderson, D., & Fisher, D. (1998). Assessing learning environments in senior science laboratories. *Australian Science Teachers' Journal*, 44, 57-62.
- Hirata, S., & Sako, T. (1998). Perceptions of school environment among Japanese junior high school, non-attendant, and juvenile delinquent students. *Learning Environment Research*, 1, 321-331.
- Ho, H.Z., Senturk, D., Lam, A.G., Zimmer, J.M., Hong, S., & Okamoto, Y. (2000). The affective and cognitive dimensions of math anxiety: A cross-national study. *Journal for Research in Mathematics Education*, 31, 362-379.
- Holland, B.S., & Copenhaver, M. (1988). Improved Bonferroni-type multiple testing procedures. *Psychological Bulletin*, 104, 145-149.
- Jaccard, J., & Wan, C.K. (1996). *LISREL approaches to interaction effects in multiple regression*. Thousand Oaks, CA: Sage Publications.
- Jackson, C.D., & Leffingwell, R.J. (1999). The role of instructor in creating math anxiety in students from kindergarten through college. *Mathematics Teacher*, 92, 583-586.
- Jegede, O.J., Fraser, B.J., & Fisher, D.L. (1995). The development and validation of a distance and open learning environment scale. *Educational Technology Research and Development*, 43, 90-93.
- Joiner, K.F., Malone, J.A., & Haines, D.H. (2002). Assessment of classroom environments in reformed calculus education. *Learning Environments Research*, 5, 51-76.

- Joyce, B.A., & Farenga, S.J. (1999). Informal science experience, attitudes, future interest in science, and gender of high-ability students: An exploratory study. *School Science and Mathematics, 99*, 431-437.
- Kazelskis, R. (1988). Some dimensions of mathematics anxiety: A factor analysis across instruments. *Educational and Psychological Measurement, 58*, 623-633.
- Kazelskis, R., Reeves, C., Kersh, M.E., Bailey, G., Cole, K., Larmon, M., Hall, L., & Holliday, D.C. (2000). Mathematics anxiety and test anxiety: Separate constructs? *Journal of Experimental Education, 68*, 137-146.
- Khine, M.S., & Fisher, D.L. (2001, December). *Classroom environment and teachers' cultural background in secondary science classes in an Asian context*. Paper presented at the annual meeting of the Australian Association for Research in Education, Perth, Australia.
- Khine, M.S., & Fisher, D.L. (2002, April). *Analysing interpersonal behaviour in science classrooms: Associations between students' perceptions and teachers' cultural background*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans, LA.
- Khoo, H.S., & Fraser, B.J. (1998, April). *Using classroom environment dimensions in the evaluation of adult computer courses*. Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.
- Kim, H.B., Fisher, D.L., & Fraser, B.J. (2000). Classroom environment and teacher interpersonal behaviour in secondary school classes in Korea. *Evaluation and Research in Education, 14*, 3-22.

- Kim, H.B., & Kim, D.Y. (1995). Survey on the perceptions towards science laboratory classroom environment of university students majoring in education. *Journal of the Korean Association for Research in Science Education*, 14, 163-171.
- Kim H.B., & Kim D.Y. (1996). Middle and high school students' perceptions of science laboratory and their attitudes in science and science subjects. *Journal of the Korean Association for Research in Science Education*, 16, 210-216.
- Klopfer, L.E. (1971). Evaluation of learning in science. In B.S. Bloom, J.T. Hastings, & G.F. Madaus (Eds.), *Handbook on summative and formative evaluation of student learning* (pp. 559-641). New York: McGraw-Hill.
- Leary, T. (1957). *An interpersonal diagnosis of personality*. New York: Ronald-Press Company.
- Leder, G.C. (1992). Mathematics and gender: Changing perspectives. In D.A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 597-622). New York: Macmillan Publishing.
- Lee, S.S.U., & Fraser, B.J. (2001, March). *High school science classroom learning environments in Korea*. Paper presented at the annual meeting of the National Association of Research in Science Teaching, St. Louis, MO.
- Lee, S.S.U., & Fraser, B.J. (2002, April). *Laboratory classroom environments in Korean high schools*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.
- Lester, D., & Hand, S. (1989). Locus of control and mathematics anxiety as predictors of performance in a psychological statistics course. *Perceptual and Motor Skills*, 69, 504-510.

- Levine, G. (1995). Closing the gender gap: Focus on mathematics anxiety. *Contemporary Education*, 67, 42-45.
- Lewin, K. (1936). *Principles of topological psychology*. New York: McGraw.
- Lott, K. (2002, April). *The evaluation of a statewide in-service and outreach program – Preliminary findings*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans, LA.
- Ma, X. (1997). Reciprocal relationships between attitude towards mathematics and achievement in mathematics. *The Journal of Educational Research*, 90, 221-229.
- Ma, X. (2003). Effects of early acceleration of students in mathematics on attitudes towards mathematics and mathematics anxiety. *Teachers College Record*, 105, 438-464.
- Ma, X., & Kishor, N. (1997). Assessing the relationship between attitude towards mathematics and achievement in mathematics: A meta-analysis. *Journal for Research in Mathematics Education*, 28, 26-47.
- Maor, D., & Fraser, B.J. (1996). Use of classroom environment perceptions in evaluating inquiry-based computer assisted learning. *International Journal of Science Education*, 18, 401-421.
- Margianti, E.S., Fraser, B.J., & Aldridge, J.M. (2002, April). *Learning environments, attitudes and achievement: Assessing the perceptions of Indonesian university students*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

- Martin-Dunlop, C., & Fraser, B.J. (2004, April). *Learning science can be fun: Changing future elementary teachers' ideas about laboratory learning*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Vancouver, BC.
- Martinez, J.G.R., & Martinez, N.C. (1996) *Math without fear*. Needham Heights, MA: Allyn and Bacon.
- Mason, L. (2003). High school students' beliefs about maths, mathematical problem solving, and their achievement in maths: A cross-sectional study. *Educational Psychology, 23*, 73-85.
- McKnight, C., Magid, A., Murphy, T.J., & McKnight, M. (2000). *Mathematics education research: A guide for the research mathematician*. Providence, RI: American Mathematical Society.
- McLeod, D.B. (1992). Research on affect in mathematics education: A reconceptualization. In D.A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 575-596). New York: Macmillan Publishing.
- Meece, J.L. (1981). *Individual differences in the affective reactions of middle and high school students to mathematics: A social cognitive perspective*. Unpublished doctoral dissertation, University of Michigan.
- Meece, J.L., Wigfield, A., & Eccles, J.S. (1990). Predictors of math anxiety and its influence on young adolescents' course enrollment intentions and performance in mathematics. *Journal of Educational Psychology, 82*, 60-70.

- Melancon, J.G., Thompson, B., & Becnel, S. (1994). Measurement integrity of scores from the Fennema-Sherman mathematics attitudes scales: The attitudes of public school teachers. *Educational and Psychological Measurement, 54*, 187-192.
- Miles, M.B., & Huberman, A.M. (1984). *Qualitative data analysis*. Beverly Hills, CA: Sage Publishing.
- Moos, R.H. (1974). *The Social Climate Scales: An overview*. Palo Alto, CA: Consulting Psychologists Press.
- Moos, R.H. (1979). *Evaluating educational environments: Procedures, measures, findings, and policy implications*. San Francisco, CA: Jossey-Bass.
- Moos, R.H., & Trickett, E.J. (1987). *Classroom Environment Scale manual* (2nd ed.) Palo Alto, CA: Consulting Psychologists Press.
- Moss, C.H., & Fraser, B.J. (2001, April). *Using environment assessments in improving teaching and learning in high school biology classrooms*. Paper presented at the annual meeting of the American Educational Research Association, Seattle, WA.
- Mulhern, F., & Rae, G. (1998). Development of a shortened form of the Fennema-Sherman mathematics attitude scales. *Educational and Psychological Measurement, 58*, 295-306.
- Murray, H.A. (1938). *Explorations in personality*. New York: Oxford University Publishing.

- Nix, R.K., Fraser, B.J., & Ledbetter, C.E. (2003, April). *Evaluating an integrated science learning environment using a new form of the Constructivist Learning Environment Survey*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.
- Novick, M.R., & Lewis, C. (1967). Coefficient alpha and the reliability of composite measurements. *Psychometrika*, 32, 1-13.
- Ntuli, S., Aldridge, J.M., & Fraser, B.J. (2003, April). *Using learning environment assessments to improve elementary school teaching during a distance inservice course in South Africa*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.
- Oberlin, L. (1982). How to teach children to hate mathematics. *School Science and Mathematics*, 82, 261.
- Patton, M.Q. (1990). *Qualitative evaluation and research methods* (2nd ed.) Newbury Park, CA: Sage Publications.
- Pearce, D.K., & Reiter, S.A. (1985). Regression strategies when multicollinearity is a problem: A methodological note. *Journal of Accounting Research*, 1, 405-407.
- Pickett, L.H., & Fraser, B.J. (2002, April). *The role of learning environment, achievement, and student and teacher attitudes in a science mentoring program for beginning elementary school teachers*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

- Pickett, L.H., & Fraser, B.J. (2004, April). *An evaluation of a science mentoring program for beginning elementary school teachers in terms of learning environment, student achievement and attitudes, and teacher attitudes*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Vancouver, BC.
- Plake, B.S., & Parker, C.S. (1982). The development and validation of a revised version of the mathematics anxiety rating scale. *Educational and Psychological Measurement*, 42, 551-557.
- Quek C.L., Fraser, B.J., & Wong, A.F.L. (2001, December). *Determinants and effects of perceptions of Chemistry classroom learning environments in secondary school gifted education classes in Singapore*. Paper presented at the annual conference of the Australian Association for Research in Education, Fremantle, Australia.
- Raaflaub, C.A., & Fraser, B.J. (2002, April). *Investigating the learning environment in Canadian mathematics and science classrooms in which laptop computers are used*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.
- Rachman, S. (1998). *Anxiety*. East Sussex, UK: Psychology Press.
- Rentoul, A.J., & Fraser, B.J. (1979). Conceptualization of enquiry-based or open classroom learning environments. *Journal of Curriculum Studies*, 11, 233-245.
- Riah, H., & Fraser, B.J. (1998, April). *Chemistry learning environment and its association with students' achievement in chemistry*. Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.

- Richardson, F.C., & Suinn, R.M. (1972). The mathematics anxiety rating scale: Psychometric data. *Journal of Counseling Psychology, 19*, 551-554.
- Roth, W.-M. (2000). Learning environments research, lifeworld analysis, and solidarity in practice. *Learning Environments Research, 2*, 225-247.
- Sandman, R.S. (1980). The mathematics attitude inventory: Instrument and users' manual. *Journal for Research in Mathematics Education, 11*, 148-149.
- Schumacker, R.E., Mount, R.E., & Monahan, M.P. (2002, April). *Multiple regression and discriminant analysis revisited*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.
- Sebela, M.P., Aldridge, J.M., & Fraser, B.J. (2003, April). *Using teacher action research to promote constructivist classroom environments in elementary schools in South Africa*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.
- She, H.C., & Fisher, D.L. (2000). The development of a questionnaire to describe science teacher communication behavior in Taiwan and Australia. *Science Education, 84*, 706-726.
- Sherman, B.F., & Wither, D.P. (2003). Mathematics anxiety and mathematics achievement. *Mathematics Education Research Journal, 15*, 138-150.
- Silverman, D. (2000). Analyzing talk and text. In N.K. Denzin & Y.S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed.) (pp. 821-834). Thousand Oaks, CA: Sage Publications.
- Sinclair, B.B., & Fraser, B.J. (2002). Changing classroom environments in urban middle schools. *Learning Environments Research, 5*, 301-328.

- Smist, J.M., & Owen, S.V. (1994, April). *Explaining science self-efficacy*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.
- Soerjaningsih, W., Fraser, B.J., & Aldridge, J.M. (2001, April). *Achievement, satisfaction and learning environment among Indonesian computing students at the university level*. Paper presented at the annual meeting of the American Educational Research Association, Seattle, WA.
- Spanos, A., & McGuirk, A. (2002). The problem of near-multicollinearity revisited: Erratic vs systematic volatility. *Journal of Econometrics*, 2, 365-393.
- Spielberger, C.D. (1972). Anxiety as an emotional state. In C.D. Spielberger (Ed.), *Anxiety: Current trends in theory and research* (pp. 23-49). New York: Academic Press.
- Spinner, H. & Fraser, B.J. (in press). Evaluation of an innovative mathematics program in terms of classroom environment, student attitudes, and conceptual development. *International Journal of Science and Mathematics Education*.
- SPSS (2001). *SPSS statistical computer program, v. 11*. Chicago, IL: SPSS Inc.
- Stern, G.G., Stein, M.I., & Bloom, B.S. (1956). *Methods in personality assessment*. Glencoe, IL: Free Press.
- Suinn, R.M., Edie, C.A., Nicoletti J., & Spinelli, P.R. (1972). The MARS, a measure of mathematics anxiety: Psychometric data. *Journal of Clinical Psychology*, 28, 373-375.
- Suydam, M.N. (1984). Research report: Attitudes towards mathematics. *Arithmetic Teacher*, 32, 12.

- Taylor, P.C., & Fraser, B.J. (1991, April). *Development of an instrument for assessing constructivist learning environments*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.
- Taylor, P.C., Dawson, V., & Fraser, B.J. (1995, April). *Classroom learning environments under transformation: A constructivist perspective*. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.
- Taylor, P.C., Fraser, B.J., & Fisher, D.L. (1997). Monitoring constructivist classroom learning environments. *International Journal of Educational Research*, 27, 293-302.
- Templeton, R.A., & Johnson, C.E. (1998). Making the school environment safe: Red Rose's formula. *Learning Environment Research*, 1, 35-57.
- Tobias, S. (1978). *Overcoming math anxiety*. Boston, MA: Houghton Mifflin Company.
- Tobin, K.G., & Fraser, B.J. (1998). Qualitative and quantitative landscapes of classroom learning environments. In B.J. Fraser & K.G. Tobin (Eds.), *International handbook of science education* (pp. 623-640). Dordrecht, The Netherlands: Kluwer.
- Vanayan, M., White, N., Yuen, P., & Teper, M. (1997). Beliefs and attitudes towards mathematics among third- and fifth-grade students: A descriptive study. *School Science and Mathematics*, 97, 345-351.
- Vehkalahti, K. (2000). *Reliability of measurement scales: Tarkkonen's general method supersedes Cronbach's alpha*. Helsinki, Finland: Finnish Statistical Society.
- Wainer, H., & Robinson, D. (2003). Shaping up the practice of null hypothesis significance testing. *Educational Researcher*, 32, 22-30.

- Walberg, H.J., & Anderson, G.J. (1968). Classroom climate and individual learning. *Journal of Educational Psychology*, 59, 414-419.
- Waldrip, B.G., & Fisher, D.L. (2001). Teacher-student interactions and teacher competence in primary science. *Academic Exchange Quarterly*, 5, 148-153.
- White, J.A.R., & Richardson, G.D. (1993, November). *Comparison of science attitudes among middle and junior high school students*. Paper presented at the annual meeting of the Mid-South Educational Research Association, New Orleans, LA.
- Whitehead, A.N. (1911). *An Introduction to Mathematics*. London: Williams and Norgate.
- Wigfield, A., & Meece, J.L. (1988). Math anxiety in elementary and secondary school students. *Journal of Educational Psychology*, 80, 210-216.
- Williamson, P., & Mattiske, J. (2002, July). *Influence of outcome expectancy and uncertainty on statistics anxiety and achievement among psychology undergraduates*. Paper presented at the Sixth International Conference on Teaching Statistics, Durban, South Africa.
- Wong, A.F.L., & Fraser, B.J. (1994). *Science laboratory classroom environments and student attitudes in chemistry classes in Singapore*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.
- Wong, A.F.L., & Fraser, B.J. (1996). Environment-attitude associations in the chemistry laboratory classroom. *Research in Science and Technological Education*, 14, 91-102.

- Wubbels, T., & Levy, J. (Eds.). (1993). *Do you know what you look like: Interpersonal relationships in education*. London: Falmer Press.
- Yarrow, A., Millwater, J., & Fraser, B. (1997). Improving university and primary school classroom environments through preservice teachers' action research. *International Journal of Practical Experiences in Professional Education, 1*, 68-93.
- Zandvliet, D.B. (2002). Learning environments in technology-rich classrooms. In S.C. Goh & M.S. Khine (Eds.) *Studies in educational learning environments: An international perspective* (pp. 49-72). Singapore: World Scientific.
- Zandvliet, D.B., & Fraser, B.J. (1998, April). *The physical and psychosocial environments associated with classrooms using new information technologies*. Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.
- Zandvliet, D.B., & Man, U.B. (2003, April). *Validation of the "What is happening in this classroom" questionnaire for the use in learning environments in Malaysian 'Smart School' classrooms*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.
- Zandvliet, D.B., & Straker, L.M. (2001). Physical and psychosocial aspects of the learning environment in information technology rich classrooms. *Ergonomics, 44*, 838-857.
- Zaslavsky, C. (1994). *Fear of math*. New Brunswick, NJ: Rutgers University Press.
- Zettle, R.D., & Raines, S.J. (2000). The relationship of trait and test anxiety with mathematics anxiety. *College Student Journal, 34*, 246-258.

Appendix A

What Is Happening In this Class? (WIHIC) Learning Environment Questionnaire

What is Happening In This Class?

Identify how you feel today regarding the following statements using the scale below:

*I **almost never** feel this way in class.*

*I **seldom** feel this way in class.*

*I **sometimes** feel this way in class.*

*I **often** feel this way in class.*

*I **almost always** feel this way in class.*

Please use the answer sheet provided, remembering to supply information at the top of the form.

Describe how you feel today about this class...

1. I make friends among students in this class.
2. I know other students in this class.
3. I am friendly to members of this class.
4. Members of the class are my friends.
5. I work well with other class members.
6. I help other class members who are having trouble with their work.
7. Students in this class like me.
8. In this class, I get help from other students.

9. The teacher takes a personal interest in me.
10. The teacher goes out of his/her way to help me.
11. The teacher considers my feelings.
12. The teacher helps me when I have trouble with the work.
13. The teacher talks with me.
14. The teacher is interested in my problems.
15. The teacher moves about the class to talk with me.
16. The teacher's questions help me to understand.

17. I discuss ideas in this class.
18. I give my opinions during class discussions.
19. The teacher asks me questions.
20. My ideas and suggestions are using during classroom discussions.
21. I ask the teacher questions.
22. I explain my ideas to other students.
23. Students discuss with me how to go about solving problems.
24. I am asked to explain how I solve problems.

25. I carry out investigations to test my ideas.
 26. I am asked to think about the evidence for my statements.
 27. I carry out investigations to answer questions coming from discussions.
 28. I explain the meaning of statements, diagrams, and graphs.
 29. I carry out investigations to answer questions that puzzle me.
 30. I carry out investigations to answer teacher's questions.
 31. I find out answers to questions by doing investigations.
 32. I solve problems by using information obtained from my own investigations.
-
33. Getting a certain amount of work done is important to me.
 34. I do as much as I set out to do.
 35. I know the goals for this class.
 36. I am ready to start class on time.
 37. I know what I am trying to accomplish in this class.
 38. I pay attention during this class.
 39. I try to understand the work in this class.
 40. I know how much work I have to do.
-
41. I cooperate with other students when doing assignment work.
 42. I share my books and resources with other students when doing assignments.
 43. When I work in groups in this class, there is teamwork.
 44. I work with other students on projects in this class.
 45. I learn from other students in this class.
 46. I work with other students in this class.
 47. I cooperate with other students on class activities.
 48. Students work with me to achieve class goals.
-
49. The teacher gives as much attention to my questions as to other students' questions.
 50. I get the same amount of help from the teacher as do other students.
 51. I have the same amount of say in this class as other students do.
 52. I am treated the same as other students in this class.
 53. I receive the same encouragement from the teacher as other students do.
 54. I get the same opportunity to contribute to class discussions as other students.
 55. My work receives as much praise as other students' work.
 56. I get the same opportunity to answer questions as other students.

What is Happening In This Class? Answer Sheet

Name: _____

Class: Fr So Jr Sr

School: _____

Gender: Male Female

Page 1						Page 2					
	Almost Never	Seldom	Sometimes	Often	Almost Always		Almost Never	Seldom	Sometimes	Often	Almost Always
1	1	2	3	4	5	25	1	2	3	4	5
2	1	2	3	4	5	26	1	2	3	4	5
3	1	2	3	4	5	27	1	2	3	4	5
4	1	2	3	4	5	28	1	2	3	4	5
5	1	2	3	4	5	29	1	2	3	4	5
6	1	2	3	4	5	30	1	2	3	4	5
7	1	2	3	4	5	31	1	2	3	4	5
8	1	2	3	4	5	32	1	2	3	4	5
9	1	2	3	4	5	33	1	2	3	4	5
10	1	2	3	4	5	34	1	2	3	4	5
11	1	2	3	4	5	35	1	2	3	4	5
12	1	2	3	4	5	36	1	2	3	4	5
13	1	2	3	4	5	37	1	2	3	4	5
14	1	2	3	4	5	38	1	2	3	4	5
15	1	2	3	4	5	39	1	2	3	4	5
16	1	2	3	4	5	40	1	2	3	4	5
17	1	2	3	4	5	41	1	2	3	4	5
18	1	2	3	4	5	42	1	2	3	4	5
19	1	2	3	4	5	43	1	2	3	4	5
20	1	2	3	4	5	44	1	2	3	4	5
21	1	2	3	4	5	45	1	2	3	4	5
22	1	2	3	4	5	46	1	2	3	4	5
23	1	2	3	4	5	47	1	2	3	4	5
24	1	2	3	4	5	48	1	2	3	4	5
For Evaluator's Use Only						49	1	2	3	4	5
SC	_____		TS	_____		50	1	2	3	4	5
INVMT	_____		INVST	_____		51	1	2	3	4	5
TO	_____		C	_____		52	1	2	3	4	5
E	_____					53	1	2	3	4	5
						54	1	2	3	4	5
						55	1	2	3	4	5
						56	1	2	3	4	5

Appendix B

Test of Mathematics-Related Attitudes (TOMRA)

Test of Mathematics Related Attitudes

This survey is used to measure your attitude towards mathematics and mathematics related activities. By using the following scale, answer how you feel today regarding these items on the answer sheet provided:

- SA: I **strongly agree** with the statement.
A: I **agree** with the statement.
N: I am **not sure** about the statement.
D: I **disagree** with the statement.
SD: I **strongly disagree** with the statement.

1. Mathematicians usually like to solve equations when they have a day off.
2. I would prefer to find out why something is true by doing a problem than by being told.
3. I enjoy reading about things which disagree with my previous ideas.
4. Mathematics lessons are fun.
5. Mathematicians are about as fit and healthy as other people.
6. Doing problems is not as good as finding out information directly from teachers.
7. I dislike doing similar problems to make sure I am understanding the concept.
8. I dislike math lessons.
9. Mathematicians do not have enough time to spend with their families.
10. I would prefer to do problems than read about them.
11. I am curious about the world in which we live.
12. School should have more math lessons each week.
13. Mathematicians like sports as much as other people do.

14. I would rather agree with people than investigate a problem to find out for myself.
15. Finding out about new things is unimportant.
16. Math lessons bore me.
17. Mathematicians are less friendly than other people.
18. I would prefer to do my own problems than have a teacher explain them.
19. I like to listen to people whose opinions are different from mine.
20. Mathematics is one of the most interesting school subjects.
21. Mathematicians can have a normal family life.
22. I would rather find out about things by asking an expert than working on my own.
23. I find it boring to hear about new ideas.
24. Math lessons are a waste of time.
25. Mathematicians do not care about their working conditions.
26. I would rather solve a problem by experimenting than be told the answer.
27. In mathematics problems, I like to use new methods which I have not used before.
28. I really enjoy going to mathematics lessons.

29. Mathematicians are just as interested in art and music as other people are.
30. It is better to ask the teacher the answer than to find out by trying a problem.
31. I am unwilling to change my ideas when evidence shows that the ideas are poor.
32. The material covered in math lessons is uninteresting.
33. Few mathematicians are happily married.
34. I would prefer to do a problem on a topic than to read about it in a textbook.
35. In mathematics problems, I identify unexpected results as well as expected ones.
36. I look forward to math lessons.
37. If you met a mathematician, he would probably look like anyone else you might meet.
38. It is better to be told mathematical facts than to find them out from problem solving.
39. I dislike listening to other people's opinions.
40. I would enjoy school more if there were no math lessons.

**SCALE ALLOCATION AND SCORING FOR EACH
ITEM OF THE TOMRA**

(N) Normality of Mathematicians	(I) Attitude towards Mathematics Inquiry	(A) Adoption of Mathematics Attitudes	(E) Enjoyment of Mathematics Lessons
1 (-)	2 (+)	3 (+)	4 (+)
5 (+)	6 (-)	7 (-)	8 (-)
9 (-)	10 (+)	11 (+)	12 (+)
13 (+)	14 (-)	15 (-)	16 (-)
17 (-)	18 (+)	19 (+)	20 (+)
21 (+)	22 (-)	23 (-)	24 (-)
25 (-)	26 (+)	27 (+)	28 (+)
29 (+)	30 (-)	31 (-)	32 (-)
33 (-)	34 (+)	35(+)	36 (+)
37 (+)	38 (-)	39 (-)	40 (-)

For positive items (+), responses SA, A, N, D, SD are scored 5, 4, 3, 2, 1, respectively. For negative items (-), responses SA, A, N, D, SD, are scored 1, 2, 3, 4, 5, respectively. Omitted or invalid responses are scored 3.

Test of Mathematics-Related Attitudes

Answer Sheet

Name: _____ Year/Class: _____

School: _____ Gender: M F

Page 1						Page 2						Page 3					
Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree		Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree		Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	SA	A	N	D	SD	14	SA	A	N	D	SD	29	SA	A	N	D	SD
2	SA	A	N	D	SD	15	SA	A	N	D	SD	30	SA	A	N	D	SD
3	SA	A	N	D	SD	16	SA	A	N	D	SD	31	SA	A	N	D	SD
4	SA	A	N	D	SD	17	SA	A	N	D	SD	32	SA	A	N	D	SD
5	SA	A	N	D	SD	18	SA	A	N	D	SD	33	SA	A	N	D	SD
6	SA	A	N	D	SD	19	SA	A	N	D	SD	34	SA	A	N	D	SD
7	SA	A	N	D	SD	20	SA	A	N	D	SD	35	SA	A	N	D	SD
8	SA	A	N	D	SD	21	SA	A	N	D	SD	36	SA	A	N	D	SD
9	SA	A	N	D	SD	22	SA	A	N	D	SD	37	SA	A	N	D	SD
10	SA	A	N	D	SD	23	SA	A	N	D	SD	38	SA	A	N	D	SD
11	SA	A	N	D	SD	24	SA	A	N	D	SD	39	SA	A	N	D	SD
12	SA	A	N	D	SD	25	SA	A	N	D	SD	40	SA	A	N	D	SD
13	SA	A	N	D	SD	26	SA	A	N	D	SD						
						27	SA	A	N	D	SD						
						28	SA	A	N	D	SD						
For Evaluator's Use Only																	
N _____ I _____ A _____ E _____																	

Appendix C

Revised Mathematics Anxiety Ratings Scale (RMARS)

Mathematics Anxiety Inventory

The items in this questionnaire refer to things and experiences that could cause fear or apprehension in you. Answer each item below to indicate how you feel today by circling:

- 1= you are **not at all** anxious
- 2= you are **a little** anxious
- 3= you are **moderately** anxious
- 4= you are **pretty much** anxious
- 5= you are **very** anxious

Work quickly and be sure to answer each item individually on the answer sheet provided.

How would you feel today if you were...

1. Watching a teacher work an algebra equation on the blackboard.
2. Being given a mathematics textbook on the first day of class.
3. Being given a homework assignment of difficult problems which is due the next class meeting.
4. Thinking about an upcoming mathematics test the day before you take it.
5. Solving a square root problem.
6. Reading and interpreting graphs and charts.
7. Getting your schedule and seeing a mathematics class on it.
8. Listening to another student explain a mathematics formula to you.
9. Walking into a mathematics class.
10. Looking through the pages of a mathematics textbook.
11. Starting a new chapter in a mathematics class.
12. Walking onto campus and thinking about a mathematics course.
13. Picking up a mathematics textbook to begin working on a homework assignment.

14. Taking an examination (quiz) in a mathematics course.
15. Reading a word associated with mathematics, such as "geometry" or "average".
16. Working on an abstract mathematical word problem.
17. Reading a formula in a science class.
18. Taking an examination (final) in a mathematics class.
19. Getting ready to study for a mathematics test.
20. Being given an unannounced quiz in a mathematics class.
21. Waiting to receive a mathematics test on which you expected to do well.
22. Listening to a lecture in a mathematics class.
23. Having to use a calculator or table to solve a problem.
24. Being told how to solve an algebra equation or write a geometry proof.

Mathematics Anxiety Inventory

Answer Sheet

Name: _____

Year/Class: _____

School: _____

Gender: M F

Page 1						Page 2					
	Not At All	A Little	Moderately	Pretty Much	Very Much		Not At All	A Little	Moderately	Pretty Much	Very Much
1	1	2	3	4	5	14	1	2	3	4	5
2	1	2	3	4	5	15	1	2	3	4	5
3	1	2	3	4	5	16	1	2	3	4	5
4	1	2	3	4	5	17	1	2	3	4	5
5	1	2	3	4	5	18	1	2	3	4	5
6	1	2	3	4	5	19	1	2	3	4	5
7	1	2	3	4	5	20	1	2	3	4	5
8	1	2	3	4	5	21	1	2	3	4	5
9	1	2	3	4	5	22	1	2	3	4	5
10	1	2	3	4	5	23	1	2	3	4	5
11	1	2	3	4	5	24	1	2	3	4	5
12	1	2	3	4	5						
13	1	2	3	4	5						
LMA Score		MEA Score									
_____		_____									

Appendix D

Permission to Copy/Amend RMARS

June 18, 2002

Bret A. Taylor
Asst. Professor of Mathematics
Chair, Natural Sciences Division
Concordia University – Irvine
1530 Concordia West
Irvine, CA 92612

Dear Mr. Taylor:

I am enclosing a copy of the Revised Mathematics Anxiety Rating Scale (called "Attitude Survey). You have my permission to copy, retype or reformat this instrument to suit your needs. However, if you change the rating scale or item order, you may distort the applicability of the psychometric properties for the scale.

I hope you find the instrument useful for your research purposes.

Barbara S. Plake, Ph.D.
Director, Buros Center for Testing

Appendix E

Student Consent Form

Consent to Act as a Human Research Subject
Concordia University, Irvine

***The Influence of Classroom Environment on High School
Students' Mathematics Anxiety and Attitudes***

Bret A. Taylor
Assistant Professor of Mathematics
949-854-8002 x1825

Name of
Subject/Student: _____

School: _____ Teacher's Name: _____ Grade Level: _____

Purpose of Study: You have been asked to participate in a research project designed to measure the relationship between a person's mathematics anxiety, his/her attitude towards mathematics, and his/her classroom environment that involves the factors of student cohesiveness, teacher support, involvement, investigation, task orientation, cooperation, and equity.

Procedures: If you agree to participate in this study, you will be asked to complete three surveys: one that measures mathematics anxiety; another that measures attitude towards mathematics; and a final survey that measures the current classroom environment. These surveys will be taken at the beginning or end of a mathematics class at your school. You may also be asked to be a part of a short interview regarding any or all of these areas, which will take place at a convenient time for all involved.

Risks: There are no risks involved in this study, and it will not be a detriment to the classroom or the instruction that is taking place.

Benefits: Results of the individual surveys will be shared with you if so desired. With the results of the survey may come a better understanding of your interaction with mathematics and possible things that can be done to help yourself and others be less math anxious.

Compensation: No compensation will be given during this study. All responses and answers will be on a volunteer basis only.

Your rights:

1. Participation in research is entirely voluntary. You may refuse to participate or may withdraw from participation at any time without jeopardy to future medical care, employment, student status or other entitlements. The researcher may withdraw you at his professional discretion also.
2. If, during the course of this study, significant new information that has been developed becomes available, which may relate to your willingness to continue to participate, this information will be provided to you by the researcher.
3. Confidentiality will be protected to the extent provided by the law.
4. If at any time you have any questions regarding the research or your participation, you should contact me at the number listed on the top and I must answer all questions you have.
5. If at any time you have comments or complaints relating to the conduct of this research or questions about your rights as a research subject, you should contact the Concordia University Human Research Committee's office at 949-854-8002 x1715.

Signature of Subject

Date: ___ / ___ / ___

Signature of Parent/Guardian

Signature of Witness

Appendix F

Example of Letter to Principals/Teachers

December 17, 2002

Dr. John Dahlem
Loara HS
1765 W. Cerritos Ave.
Anaheim, CA 92804

Dear Dr. Dahlem,

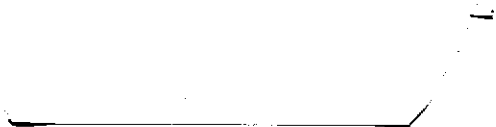
Thank you for your willingness to help with the data collection for my doctoral research. I've enclosed a few things for you and listed them below:

- Letter of consent for minors and their guardians to sign.
- A letter of approval from the Human Research Committee here at Concordia in case someone needs it.
- A survey instrument called, "What Is Happening in This Class?" (2 pages plus answer sheet).
- An instrument called "Mathematics Anxiety Inventory" (2 pages plus answer sheet).
- The final instrument called "Test of Mathematics Related Attitudes" (3 pages plus answer sheet).

Most schools are making a classroom set of the instruments and then enough answer sheets for each student. This saves a lot of paper as students can reuse the questions in the next class.

After the data has been collected and run, I may be returning to school to do some interviewing of a few students in February, provided you give me permission to do so.

Thank you again! Please contact me if there are any questions or any problems!



Bret A. Taylor
Concordia University – Irvine
949-854-8002 x1825

Appendix G

Interview Questions and Protocol

Method for determining interviewees: Interview candidates are determined by scores from the Revised Mathematics Anxiety Ratings Scale and recommendation of their instructor.

Introduction (Interviewer): Hello! How are you today? Thanks for coming out to speak to me. My name is Bret Taylor and I am collecting data for my doctoral research. I am investigating how what takes place in a typical high school mathematics classroom influences whether a student has anxiety about mathematics and what they feel about math. Do you remember those surveys you filled out a few weeks ago? That was the beginning of this project and now I am trying to double check what those questionnaires came up with. Are you ready?

Questions:

What is your name?

What grade are you in?

What math class are you taking presently?

What did you take last year?

Describe your comfort level with mathematics in your present mathematics class.

Is this the same as previous years or has it changed recently?

Describe your comfort level with mathematics outside of the classroom, such as where you work or just away from school.

Is there a noticeable difference between how you feel about mathematics here at school compared to when you are away from school?

Give me a time when you felt uncomfortable in a mathematics class?

What was going on around you during that time?

Did anything happen that took that uncomfortable feeling away or diminish it?

How important is it for you to know the other students in your mathematics class or feel comfortable with them?

Why or why not?

What are some benefits/damage that you experience because of this belief?

Are there certain things teachers can do to make a classroom feel better socially?

What else do teachers do that help you feel better about mathematics or help your attitude?

Are there things that teachers do or certain things in the classroom that make you feel more anxious about mathematics or hurt your attitude?

This is the final question I have...

I'm looking for an analogy or comparison of how a mathematics classroom feels to you today. Is there some place away from school where you get similar feelings to how you feel inside the math classroom? One way to do this is to complete the following sentence: "I feel the same as I do in mathematics class when I am...." Where?

Conclusion:

Thank you for your time. Is there anything about this interview or the questionnaires that you would like to tell me that I haven't asked you about? I appreciate your help with this!