Science and Mathematics Education Centre

Evaluating Online Resources in Terms of Classroom Environment and Student Attitudes in Middle-Grades Mathematics

James E. Earle

This thesis is presented for the Degree of

Doctor of Philosophy

of

Curtin University

September 2014

DECLARATION

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

Signature:

Date: 8/21/2014

ABSTRACT

The primary aim of this research was to evaluate the effectiveness of the online mathematics software program, FCAT Explorer, in terms of students' perceptions of their learning environment and attitudes towards mathematics in middle-school classrooms in Florida. A second goal was to investigate associations between students' perceptions of technology-supported classroom environments and their attitudes towards mathematics.

The Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) and scales selected from the Test of Mathematics Related Attitudes (TOMRA) were used in a pretest–posttest design while the online program was used as a major curriculum tool over a 10-week period. The sample consisted of 949 students in grades 6–8 in 49 classrooms. In addition, a qualitative component involved using student interviews to construct a narrative of a typical day in the classroom and to identify recurring themes.

To determine the validity of the questionnaires, principal axis factoring with varimax rotation and Kaiser normalization was used to check the structure of both pretest and posttest responses. The criteria for retention of any item were that it must have a factor loading of at least 0.40 on its own scale and less than 0.40 on other scales. The results supported the validity of the TROFLEI and TOMRA.

Associations between students' perceptions of their classroom environment and their attitudes towards mathematics were investigated using simple correlations to describe bivariate associations and multiple regression analysis to describe the multivariate association between each attitude scale and the entire set of environment scales. Analyses were conducted separately for pretest and posttest and for two units of analysis (the individual student and the class mean). In particular, student attitudes were more positive in classrooms with more Teacher Support, Involvement, Investigation and Cooperation.

To evaluate the use of FCAT Explorer in terms of students' perceptions of their classroom environment and their attitudes, MANOVA and effect sizes were used.

Over the time when the FCAT Explorer was used, students perceived significantly more Involvement, Investigation, Differentiation, and Computer Usage but less Teacher Support, Task Orientation, Cooperation and Equity; however, all effect sizes were small. Overall, the results suggest that there was neither much advantage nor much disadvantage in using the program. This finding is consistent with the ‘no discernible effect’ phenomenon that is common in research on the use of technology in the classroom. This is also consistent with qualitative interviews during which students expressed displeasure in using computers to ‘do’ mathematics.

ACKNOWLEDGEMENTS

Any project such as this requires the tireless help of many people who deserve acknowledgement. This thesis is dedicated to my lovely and supportive wife, Edie, who gave so generously of her time in proofreading endless drafts, offering support and encouragement during the entire process, and giving me the encouragement to continue with what is patently a younger person’s game. Without her, the task would not have been nearly as enjoyable. I’d also like to thank my brother, Bob, whose sardonic wit was most welcome during the times of slow passage.

My special thanks are offered to my Supervisor, Professor Barry Fraser, for his patient and helpful support during this painstaking process. It has been a pleasure to experience the extent of his knowledge and experience in this important field.

My heartfelt thanks go out to the teachers and staff of Herbert A. Ammons Middle School without whose patient assistance this project would not have been possible. Special and sincere thanks to the principal, Irwin Adler, who has been such an inspiring ‘cheerleader’ for me and for the education of children.

Finally, my special and warm thanks to the students of Ammons Middle School who continue to show us all that the future might well be in good hands.

TABLE OF CONTENTS

Chapter 1 Introduction and Background

Chapter 2 Literature Review

Chapter 3 Research Methodology

Chapter 4 Data Analyses and Results

Chapter 5 Summary, Conclusions and Recommendations

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION AND BACKGROUND

1.1 Introduction

In many countries around the world, there is a growing emphasis on measuring student achievement by means of high-stakes tests. As a result, expenditure on textbooks and technology such as computers and educational software has been increased in an attempt to help students to prepare for these tests. In Florida, the FCAT Explorer, an online software program, was designed at the direction of the Florida Department of Education to help students in grades 3 to 11 to prepare for the Florida Comprehensive Assessment Test (FCAT). As states and districts look to maximizing the return on investment in these educational resources, the efficacy of a program such as the FCAT Explorer is an important focus for research. Evaluating the effectiveness of the FCAT Explorer was the main aim of this study.

Although the FCAT Explorer has been used in its present form for over ten years and is supported by a multi-million dollar budget, little research has been undertaken to evaluate the program in terms of students' perceptions of their learning environment and their attitudes. Designing a valid evaluation of a mathematics software program in terms of high-stakes achievement test performance presents many problems. Because of privacy restrictions associated with a state test, making a direct link between using FCAT Explorer and the exact form of the FCAT test taken by students is impossible. There are a host of other factors that can influence the outcome when evaluating a software program using achievement results, such as the amount time spent by each student, access to computers both in school and at home, and the degree of congruence between the content of the FCAT Explorer and the FCAT test.

This study made use of robust instruments to assess students' perceptions of their classroom learning environment and their attitudes towards the subject of mathematics. The Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) (Aldridge & Fraser, 2008), an instrument that draws on the rich research of learning environments coupled with scales to measure student perceptions of Information Communication Technology (ICT), was used to measure the effectiveness of the FCAT Explorer in terms of grade 6–8 students' classroom environment perceptions. The TROFLEI draws heavily on the much-heralded What Is Happening In this Class? (WIHIC) questionnaire (Aldridge & Fraser, 2000) to assess classroom environment perceptions. Attitude scales based on the Test of Science-Related Attitudes (TOSRA) (Fraser, 1981a) were chosen to assess student attitudes to the subject of mathematics. The research presented in this thesis represents the first study that focused on the effectiveness of the FCAT Explorer in terms of student perceptions of their learning environment and their attitudes towards mathematics.

The first chapter is divided into several sections starting in Section 1.2 with some background information about Miami-Dade County, Florida and Ammons Middle School (where my study took place), thus providing a context for where my research was conducted. The next sections present the purposes of the study (Section 1.3) and the research questions (Section 1.4). Whereas Section 1.5 briefly considers the study's significance, Section 1.6 provides an overview of the various chapters contained in this thesis.

1.2 Background for Miami-Dade County, Florida

The Miami public school system is known as Miami-Dade County Public Schools (MDCPS) and is headed by a superintendent who reports to a nine-member school board. The student enrolment in MDCPS is 348,787 (FLDOE 2013~2014). The ethnic composition of the district comprises a majority of Hispanic students (66.7%), followed by 23.5% Black Non-Hispanic, 8% White Non-Hispanic, and 1.8% Other, a category that includes American Indian, Asian, and Multiracial. Ethnic diversity also brings language diversity. Spanish is the primary language for 188,124 students, and Haitian-Creole is the primary language for 15,771 students, with the combined total of both of these groups representing over 58% of the student population. MDCPS is the fourth largest school district in the United States following Chicago, Los Angeles, and New York.

Dade County has a total of 340 traditional schools, including 173 elementary, 43 Kindergarten to grade 8 (K–8 Centers), 60 middle schools, and 43 senior high schools. In addition to these public schools that operate under the direction of Miami-Dade County Public Schools, there are also 120 Charter Schools that operate independently from the MDCPS. Over the last decade, MDCPS has seen a surge in the number of Charter Schools, which still receive state funding for student attendance, but do not receive funds for the physical school site. Charter Schools also have significantly more freedom in their choice and administration of their academic curriculum. The number of Charter Schools reached a current total of 120, including 26 elementary, 32 K–8 Centers, 23 middle, and 32 senior high schools (MDCPS Statistical Highlights 2012~13).

Ammons Middle School, the school site where this study took place, was established in 1998 in the southern region of Dade County to serve students in grades 6 to 8. Its enrolment is 1165 students. The ethnic composition of the school is fairly close to that of MDCPS. The Hispanic enrolment is 65.1% which is very close to the district total of 66.7%. However, the Black Non-Hispanic enrolment of 12.8% is less than the district proportion of 23.5%, and the White Non-Hispanic enrolment of 17.9% is higher than the district total of 8%. The category of 'Other Countries' comprises 4.3% of the Ammons Middle School enrolment, which is small but somewhat larger than the district proportion of 1.8%.

In 2007, Ammons Middle School became the first school in the Miami-Dade County Public Schools system to be authorized as an International Baccalaureate Middle Years Programme, which is offered school-wide at all three grade levels. This program follows the guidance of the International Baccalaureate Organization based in Geneva, Switzerland, as part of an eight-subject academic path culminating in the high school Diploma Programme. One item of note is that the school is made up entirely of portable classrooms that are mobile trailers that were used as temporary housing during the reconstruction effort in southern Dade County following the widespread damage caused by Hurricane Andrew in 1992. Because the classrooms are portables, they have as many as six windows that allow an abundance of natural light into the classroom. Typically, these classrooms are well equipped.

Ammons Middle School serves 1208 students in grades 6 through 8 and operates on a block schedule. Students have a total of 8 classes on an alternating schedule of 4 classes per day. The classes taken by each student include the four core subjects of mathematics, science, language arts, and social studies. In addition, students have a reading class and study a foreign language (either Spanish or French). A mandatory half-year course in technology is coupled with physical education for the other half of the year, leaving one period for an elective including band, steel drum, guitar, chorus, art, and photography. Students are required to keep a portfolio of work in both paper and electronic form via flash drives, and must also complete a mandatory 30 hours of community service in order to obtain an IBMYP certificate.

The students start school at 9:00am each day and continue through their four-class day until 3:40pm, with a 5-minute interval between classes and a 35-minute lunch break. Most students finish lunch well within the allotted time and take advantage of free time to meet with friends in a covered recreation area called the spill-out. This brief time outdoors allows students to move about freely and let off some of their youthful exuberance and energy before returning to the classroom. Each period lasts 88 minutes, a block of time that allows for projects, presentations, laboratory exercises, and extended practice.

My research focused on evaluating the use of technology, and the school site at which the project was conducted has placed a high emphasis on technology since its inception. Several awards have been garnered by the school, such as its inclusion as one of the 100 Top Wired Schools in the United States by *Family PC* magazine (2001), Florida Council of Instructional Technology Leaders Winner (2003), Florida Top Technology Educator Award (2004–2005), and FBI Cyber Safety Award (2006~2013). The school is equipped with three computer laboratories with 36 to 40 computer terminals each, and also each classroom has a minimum of four computers for students and one computer for the teacher.

1.3 Purposes of the Study

Information communications technology (ICT) offers considerable potential in the learning environment (Aldridge, Fraser & Fisher, 2003). School districts, such as Miami-Dade County where this study was conducted, are spending large sums of money to bring computers to schools and place them in laboratories and classrooms and, in a few limited instances, in the hands of individual students in one-to-one laptop programs. Decisions to continue, discontinue, or modify these expenditures are based in part on the results of state achievement tests. However, the lack of significant improvements in achievement test scores has given rise to questions about how funds are being allocated. There is little research that supports the effectiveness of the implementation of computers in the classroom from the standpoint of the learning environment, with notable exceptions being the work by Maor (2004) and Newby and Fisher (1996). Given the correlation between student perceptions of the learning environment and student outcomes (Fraser, 2002), this study made use of available learning environment instruments to explore the impact of technology support tools in terms of student perceptions and attitudes.

Using technology to support education is not a new concept. Evidence for the effectiveness of its use in classrooms and on student achievement, however, is mixed because evaluation results can be influenced by variations between assessments, application of the technology, and students' familiarity with the technology to name but a few. A brief discussion of the use of technology in the educational setting is presented in Chapter 2, Section 2.4.5. The focus of this study was evaluating student perceptions of their learning environment and attitudes in the context of using one specific piece of technology, namely, the FCAT Explorer. A brief explanation of the FCAT Explorer is provided below in the context of its role in this study, whereas a more thorough explanation is provided as part of the review of the literature in the second chapter of this thesis.

The FCAT Explorer (FLDOE, 2005) is an online program that was started in 2000 by the Florida State Department of Education (FLDOE) to offer students practice problems in both reading and mathematics that are suitable for specific grade levels. The mathematics program has three different levels that provide benchmark-specific problems for the 5th, 8th and 10th grades. In addition to practice problems, FCAT Explorer provides Correct Answer Explanation (CAE), a feature that provides students with a cohesive explanation of the problem and its concepts when the student answers the question correctly. If the student does not answer the question correctly, the program provides a hint about how to solve the problem and immediately gives the student a second chance to apply the hint. If the student is unsuccessful at the second attempt, the program moves the student to the next problem, but places the missed problem on a challenge list. In order to complete the section, the student must answer all questions included on the challenge list. The program also provides the student with access to reference material, formulas and a calculator.

Because the program is provided as an online resource, the type, age, and operating system of the computer used to access it is not an issue; if the computer can run an internet browser, then the student can access the program. Teachers can access performance results for their students by content strand, benchmark, and by theme (unit), thereby making it relatively simple for a teacher to obtain almost real-time feedback on student performance. The performance data can be displayed for individual students or for a whole class, thus providing further options for the teacher.

FCAT Explorer is promoted by the FLDOE and by school districts throughout the state of Florida. There is, however, no information available concerning the effectiveness of this program in terms of student outcomes as one important criterion. While it is difficult to link performance results on standardized tests to a specific classroom intervention or program, it has been possible to establish associations between student outcomes and perceptions of the classroom environment (Fraser, 2014). Therefore, the classroom environment has been used as a criterion of effectiveness in investigating the effectiveness of numerous classroom strategies in much past research (Fraser, 2012).

The design chosen for this study involved administering the TROFLEI and TOMRA as a pretest and, after a specific period of time, as a posttest. The specific timing was the 10-week period between the beginning of a marking period, mid-

January, and the beginning of April when the FCAT was administered at the middle school. This differs from many other learning environment projects that have relied on a single administration involving students in providing their perceptions of the actual classroom and their preferred classroom environment. The block schedule provided a longer period of time for completing the rather lengthy 104-question TROFLEI and attitude scales in one class period.

1.4 Research Questions

The main objective of this project was to evaluate the use of online resource material for supporting a traditional mathematics curriculum by using learning environment and attitude scales chosen specifically for this study. The primary research question involved evaluating the effectiveness of the FCAT Explorer among a sample of middle-school students in terms of their learning environment perceptions and attitudes towards mathematics. A second research focus was the validation of the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) (Aldridge & Fraser, 2008) and the Test of Mathematics Related Attitudes (TOMRA) – a modified form of the Test of Science Related Attitudes (TOSRA; Fraser, 1981a) with an ethnically-diverse sample of middle-grade mathematics students in Florida. Finally, associations between classroom environment and student attitudes were investigated. The research questions for this project were:

1. Are the TROFLEI and TOMRA valid when used in technology-supported middle-school mathematics classes?
2. Is the FCAT Explorer effective as a curriculum supplement for traditional mathematics instruction in terms of:
    a. students' perceptions of their classroom learning environment
    b. students' attitudes to mathematics?
3. Are there associations between students' perceptions of technology-supported classroom environments and their attitudes to mathematics?

1.5 Significance of the Study

The significance of the project is that it provided evidence about the effectiveness of a particular online curriculum support tool in terms of the students' perceptions of their classroom environment and attitudes towards mathematics. Additionally, as far as is known, this was the first evaluation of the FCAT Explorer in terms of learning environment criteria. By providing evidence about the effectiveness of the program in terms of changes between pretest and posttest in classroom environment and attitudes, this research contributed to the growing body of studies that have involved evaluating an educational program in terms of its impact on classroom environment (Fraser, 2012).

1.6 Organization of the Thesis

This thesis consists of five chapters. Chapter 1 presented a framework and rationale for the study. Also provided was brief contextual and background information about the school district and the school in which the study was conducted. The ethnic composition at the school and an introduction to the program FCAT Explorer, which was the focus of my evaluation, were provided. Chapter 1 also discussed the purposes of the study and delineated the research questions.

The second chapter provides a review of literature relevant to my research, including the historical background for learning environment research and the many learning environment instruments that are available. Also included in the chapter is a more in-depth review of the large number of studies that have used the What Is Happening In this Class? (WIHIC), including those that investigated connections between the learning environment and student outcomes. Also presented are a review of past evaluations that employed the learning environment as criteria of effectiveness and a background discussion of the use of technology over the last century, including online mathematics resources generally and the use of FCAT Explorer in Florida specifically.

The third chapter is devoted to the research methodology, including the research design, data sources, samples, and research methods. A discussion of the instruments used in the study is also included, along with an overview of the administration process, data collection, and the statistical analysis procedures applied in the study. Finally, a discussion of the collection and analysis of qualitative information, based on student interviews, is provided.

The fourth chapter reports the data analyses and findings for the study. Included are results for the validity and reliability of the instrument, as well as for the effectiveness of the FCAT Explorer in terms of the learning environment and student attitudes. Additionally, the chapter reports my investigation of associations between the learning environment and students' attitudes towards mathematics. The qualitative component of my study is reported using a narrative and an analysis of themes emerging from interviews.

The fifth and final chapter summarizes and discusses the results of the research and includes an overview of the entire thesis. Also in this chapter is a discussion of the validity of the TROFLEI for assessing students' perceptions of their learning environment, as well as the validity of TOMRA scales for assessing students' attitudes towards mathematics. This chapter then considers some implications and limitations of the research, as well as suggesting future research possibilities for studying the use of technology in terms of student learning environment perceptions and attitudes.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

I investigated the effectiveness of the FCAT Explorer, an online mathematics resource program, in terms of middle-school students' perceptions of classroom environment and their attitudes towards mathematics. Therefore, a detailed review of the literature associated with learning environments and attitudes towards mathematics is provided in this chapter. However, because learning environment and attitude criteria have never been used for evaluating the particular program, FCAT Explorer, it is important to become familiar with previous research that has been undertaken in relation to FCAT Explorer using other criteria of effectiveness.

This chapter reviews the literature in three broad categories. The first area is the field of learning environment research, which is further subdivided into key topics including the foundations of learning environment research over the last four decades, a review of the instruments for assessing learning environment, including the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) which was used in my study, and a review of past research applications using these instruments. The second area addressed in this chapter is the field of attitude assessment, including a review of the history of the Test of Mathematics Related Attitudes (TOMRA) from which scales were chosen for my research. The third area is online resource tools. A review of the growing use of computers to support classroom activities in general, as well as specific emphasis on the program FCAT Explorer, is provided.

It is the intent of this literature review to arrive at a better understanding of these research areas, and also to identify any areas that could pose difficulties for my study. By addressing these points, a foundation for the project can be established and linked to ideas and research from the three areas.

2.2 Learning Environments Research

This section has three main parts. First, learning environments research, its history and foundations are considered (Section 2.2.1). Second, there is a discussion of the historical development of the variety of instruments used to assess classroom perceptions (Section 2.2.2), including the TROFLEI which was used in my study. Third, past research involving the use of learning environment questionnaires is reviewed (Section 2.2.3).

2.2.1 History and Foundations of Learning Environments Research

Fraser (1998a, 1998b), in his watershed work on learning environments, tells us that research and evaluation in education have relied too heavily on academic achievement. However, these measures alone do not give the most complete view of students' educational processes because their perceptions of and reactions to their learning environment are significant. It is the "conceptualising, assessing and investigating the determinants and effects of social and psychological aspects of the learning environments of classrooms and schools" (p. 527) that forms the basis of this field.

Early work in field theory by Lewin (1936) focused on the idea that the environment and the interaction of the individual in that environment are important contributors to human behavior. A needs–press model was proposed by Murray (1938) as personality characteristics were studied in the context of achieving goals. This foundational work in business settings influenced the study of environments in educational settings.

In the field of education, the work by Herbert Walberg and Rudolf Moos in the USA formed the basis of modern learning environment research. As part of an evaluation of Harvard Project Physics (Walberg & Anderson, 1968), the Learning Environment Inventory (LEI) was developed and became a widely-used research instrument. Student perceptions of the classroom environment were examined when 2100 high school juniors and seniors participated in an evaluation of the Harvard Project Physics course, which included several measurement instruments including the precursor to the LEI, namely, the Classroom Climate Questionnaire (Anderson & Walberg, 1968). The findings indicated that there existed a relationship between climate and learning, and that some climate variables were able to predict science learning or achievement in physics.

Concurrent with but independent from this work, Moos (1974) developed his scheme for categorizing human environments. Relationship Dimensions address the extent to which people are personally involved in an environment as well as their support of one another. Personal Development Dimensions assess personal growth and development. System Maintenance and System Change Dimensions address the extent to which the environment involves order, expectations and responsiveness to change. Following extensive research in hospital, prison, and university residence environments, the Classroom Environment Scale (CES) emerged (Moos, 1974; Moos & Trickett, 1974, 1987). It is from the foundations laid by Walberg and Moos that the study of classroom learning environments has developed into a significant body of research (Aldridge & Fraser, 2008; Fisher & Khine, 2006; Fraser, 1986, 2012, 2014).

While much of the classroom environment research focused on science and computer-assisted classrooms, research in the Netherlands expanded the learning environment field by drawing on a communications processes theory (Watzlawick, Beavin & Jackson, 1967) that views communication as a system in which the behaviors of the participants exert influence on each other. This theory was applied in the area of interpersonal relationships between teachers and students through the development of the Questionnaire on Teacher Interaction (QTI) (Wubbels, Créton & Hooymayers, 1985). In the system of mapping teacher interpersonal behavior, the behavior of the teacher is impacted by the behavior of the students, who are then impacted by the behavior of the teacher. The validity of the QTI has been confirmed by studies in the Netherlands (Créton & Wubbels, 1984; Wubbels & Brekelmans, 2012; Wubbels, Creton & Hooymayers, 1985), which revealed Cronbach alpha reliability coefficients higher 0.70 at the student unit of analysis, and even higher at the class unit of analysis. When the QTI was also used to examine the relationships between QTI scales and student outcomes (Wubbels & Brekelmans, 2012; Wubbels, Brekelmans, & Hooymayer, 1991), teacher behavior scales such as Strict, Leadership and Helping/Friendly were linked to higher outcome scores, while the teacher behavior scale of Student Responsibility/Freedom, Uncertain and Dissatisfied were found to impact outcome scores negatively.

The development of the field of learning environments has been facilitated in important ways by the birth of the American Educational Research Association's Special Interest Group (SIG) on Learning Environments in 1984, of Springer's *Learning Environments Research: An International Journal* in 1998, and of Sense Publishers' book series *Advances in Learning Environment Research* in 2008.

2.2.2 Learning Environment Instruments

As the body of research on classroom environments expanded, a growing variety of instruments emerged for different grade levels, school subjects and research foci. A selection of 11 classroom environment instruments is shown in Table 2.1. A more complete discussion of the historical development of each of these instruments has been given by Fraser (1998a, 1998b, 2012), and it can be seen that the development of learning environment instruments has created a substantial history of research tools. Table 1 shows, for each of the 11 instruments, the level of education for which it is applicable, the number of items per scale, and the classification of all scales according to Moos's (1974) scheme.

However, a plateau was reached with the What Is Happening In this Class? (WIHIC) questionnaire that combines modified versions of the most salient scale with additional scales that accommodate contemporary educational concerns (e.g., equity and constructivism) (Aldridge, Fraser & Huang, 1999). The WIHIC was the obvious choice for the core design elements of the next generation of instruments, including the TROFLEI which was chosen for my study. Before discussing the TROFLEI in depth, the next section briefly reviews the other learning environment instruments in Table 2.1 that preceded its development.

Table 2.1 Overview of Scales Contained in 11 Classroom Environment Instruments

			Scales Classified According to Moos's Scheme		
Instrument	Level	Items per scale	Relationship dimensions	Personal development dimensions	System maintenance and change dimensions
Learning Environment Inventory (LEI)	Secondary	7	Cohesiveness Friction Favouritism Cliqueness Satisfaction Apathy	Speed Difficulty Competitiveness	Diversity Formality Material Environment Goal Direction Disorganisation Democracy
Classroom Environment Scale (CES)	Secondary	10	Involvement Affiliation Teacher Support	Task Orientation Competition	Order and Organisation Rule Clarity Teacher Control Innovation
Individualised Classroom Environment Questionnaire (ICEQ)	Secondary	10	Personalisation Participation	Independence Investigation	Differentiation
College and University Classroom Environment Inventory (CUCEI)	Higher Education	7	Personalisation Involvement Student Cohesiveness Satisfaction	Task Orientation	Innovation Individualisation
My Class Inventory (MCI)	Elementary	6–9	Cohesiveness Friction Satisfaction	Difficulty Competitiveness	
Questionnaire on Teacher Interaction (QTI)	Primary/ Secondary	8–10	Leadership Helpful/Friendly Understanding Student Responsibility and Freedom Uncertain Dissatisfied Admonishing Strict		
Science Laboratory Environment Inventory (SLEI)	Upper Secondary/ Higher Education	7	Student Cohesiveness	Open-Endedness Integration	Rule Clarity Material Environment
Constructivist Learning Environment Survey (CLES)	Secondary	7	Personal Relevance Uncertainty	Critical Voice Shared Control	Student Negotiation
What Is Happening In this Class? (WIHIC)	Secondary	8	Student Cohesiveness Teacher Support Involvement	Investigation Task Orientation Cooperation	Equity
Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI)	Secondary	10	Student Cohesiveness Teacher support Involvement Young Adult Ethos	Investigation Task Orientation Cooperation	Equity Differentiation Computer Usage
Constructivist-Oriented Learning Environment Survey (COLES)	Secondary	11	Student Cohesiveness Teacher Support Involvement Young Adult Ethos Personal Relevance	Task Orientation Cooperation	Equity Differentiation Formative Assessment Assessment Criteria

Based on Fraser (2012)

2.2.2.1 Learning Environment Inventory (LEI)

As noted above, Herbert Walberg developed the LEI as part of research and evaluation activities of Harvard Project Physics (Walberg & Anderson 1968) before the LEI became widely used in a substantial amount of earlier research (Fraser, 1986; Fraser & Walberg, 1991; Walberg, 1979). The LEI was designed to be used at the secondary level, and it contains seven items in each of 15 scales for a total of 105 items. The response alternatives are Strongly Agree, Agree, Disagree, and Strongly Disagree. For some items, the direction of the choices, or polarity, is reversed.

2.2.2.2 Classroom Environment Scale (CES)

Also as noted above, Rudolf Moos developed the CES as part of a comprehensive program of research involving perceptual measures of a variety of human environments, including mental health facilities, correctional facilities, higher education facilities, and workplaces (Moos, 1974). The CES was also designed to be used at the secondary level and employs a True–False format containing nine scales of 10 items each (Moos & Trickett, 1974; Trickett & Moos, 1973). In Australia, Fisher and Fraser (1983) cross-validated the CES and established associations between CES scores and student outcomes (Fraser & Fisher, 1982).

2.2.2.3 Individualised Classroom Environment Questionnaire (ICEQ)

The ICEQ was the first of numerous specific-purpose learning environment instruments that focuses on student-centered classrooms instead of teacher-centered classrooms (Rentoul & Fraser, 1979). The dimensions in the ICEQ assess the environment of individualized classes as distinct from conventional ones. After an extensive literature review of inquiry-based education, interviews with teachers and junior high-school students, and review by experts, the ICEQ evolved to contain five scales of 10 items each for a total of 50 items. Students respond by choosing one of the five frequency choices of Almost Never, Seldom, Sometimes, Often, and Very Often. For some items, the direction of the choices, or polarity, is reversed. The ICEQ was used in an evaluation of the Australian Science Education Project (ASEP, Fraser, 1979) and in a study of associations between student outcomes and the nature of the classroom learning environment (Fraser & Fisher, 1982).

2.2.2.4 My Class Inventory (MCI)

The MCI owes its roots to a modification of the LEI undertaken with children aged 8–12 years as the target group (Fraser, Anderson & Walberg, 1982). A further modification by Fraser and O'Brien (1985) saw the creation of a 25-item version of the MCI. The MCI is targeted for elementary school use, but it has also been a useful learning environment instrument for junior high students who have reading difficulties. There are several differences between the LEI and MCI. First, the MCI contains only five of the LEI's 15 scales in order to make it more useable with younger children. Second, simpler wording of the items makes it more suitable for younger children. Third, the number of response alternatives is reduced from four in the LEI to two (Yes–No) in the MCI. The fourth difference is that students provide answers on the questionnaire itself rather than on a separate response sheet.

Although the LEI is used seldom in contemporary research, the low reading level of the MCI makes it a continuing choice in recent studies. Satisfactory factor structure and sound reliability were established for an English-language version of the MCI among 1,565 lower-secondary mathematics students in Brunei Darussalam (Majeed, Fraser & Aldridge, 2002). In Florida, Mink and Fraser (2005) used the MCI, attitude scales, and qualitative methods in evaluating the K–5 Project SMILE (Science and Mathematics Integrated with Literature Experiences) among 120 grade 5 mathematics students. A revised 18-item version of the MCI demonstrated sound validity and was recommended for monitoring accountability for elementary school counsellors in a study involving a sample of 2,835 grade 4–6 students in Washington State (Sink & Spencer, 2005). Scott Houston, Fraser and Ledetter (2008), in addition to providing supporting validity, used the MCI to evaluate the use of science kits in terms of learning environment criteria for a sample of 588 grade 3–5 students in Texas.

2.2.2.5 College and University Classroom Environment Inventory (CUCEI)

Classroom environment research at the college and university level initially was undertaken by Stern (1970) and later was augmented by the development of the CUCEI (Fraser & Treagust, 1986) which contains seven, seven-items scales. Using a four-response format (Strongly Agree, Agree, Disagree, and Strongly Disagree), the CUCEI incorporates polarity-reversing for about half of the items. The primary focus for the CUCEI is for smaller classes or seminars of up to 30 students. Fraser, Williamson and Tobin's (1987) use of the CUCEI in an evaluation of alternative high schools among a sample of 536 students revealed success in terms of involvement, satisfaction, innovation and individualization. However, in a study of New Zealand computing classrooms, Logan, Crump and Rennie (2006) achieved less than ideal substantiation for the CUCEI's psychometric performance.

2.2.2.6 Questionnaire on Teacher Interaction (QTI)

As noted in Section 2.2.1, research on the nature and quality of interpersonal relationships between teachers and students originated in the Netherlands (Creton, Hermans & Wubbels, 1990; Wubbels & Brekelmans, 2005, 2012; Wubbels & Levy, 1993). Using the theoretical model of proximity (cooperation–opposition) and influence (dominance–submission), the QTI assesses student perceptions of eight aspects of behavior and employs a five-point response format ranging from Never to Always. The QTI has been validated in many international studies, including the USA (Wubbels & Levy, 1993), Singapore (Goh & Fraser, 1996), Brunei Darussalam (Scott & Fisher, 2004), Indonesia (Margianti, Aldridge & Fraser, 2004), Singapore (Quek, Wong, & Fraser, 2005) and Korea (Lee, Fraser, & Fisher 2003; Kim, Fisher, & Fraser, 2000). The QTI also has been validated at the university level in the Indonesian language (Fraser, Aldridge, & Soerjaningsih, 2010). Brekelmans, Wubbels and van Tartwijk (2005) reported interesting changes in teacher interpersonal behaviors across the duration of the teaching career.

2.2.2.7 Science Laboratory Environment Inventory (SLEI)

This instrument was developed to address the specific application of secondary and higher education science laboratory classes (Fraser, Giddings & McRobbie, 1995; Fraser & McRobbie, 1995; Fraser, McRobbie, & Giddings, 1993). With seven items in each of its five scales, the SLEI employs a five-response frequency format of Almost Never, Seldom, Sometimes, Often and Very Often. The SLEI was initially validated in a multi-national study (USA, Canada, England, Israel, Australia, and Nigeria) with a sample of 5,447 students in 269 classes (Fraser & McRobbie, 1995), and it was cross-validated with 489 students in Australia (Fisher, Henderson, & Fraser, 1997; Henderson, Fisher & Fraser, 2000).

As an indication of the growing sophistication in the application of learning environment instruments, a Korean-language version of the SLEI was used to study classroom environment differences between three study tracks (science-independent, science-oriented and humanities). The SLEI demonstrated satisfactory factorial validity and internal consistency reliability. Additionally, the study was able to demonstrate more favorable student perceptions in the science-independent track as compared to the other two tracks (Fraser & Lee, 2009).

In Miami, Florida, a study among a sample of 761 high-school biology students provided additional support for the SLEI’s factorial validity and internal consistency reliability, as well as its ability to differentiate between classrooms (Lightburn & Fraser, 2007). The study used student outcomes, including achievement and attitudes, and the classroom environment as criteria in evaluating the use of anthropometric activities.

In Singapore, Wong and Fraser modified the SLEI to form the Chemistry Laboratory Environment Inventory by changing the word ‘science’ to ‘chemistry’ (Wong & Fraser, 1996; Wong, Young & Fraser, 1997). They validated the CLEI with 1592 high-school chemistry students in 28 classes, as well as establishing associations between classroom environment and student attitudes. In a later study involving the CLEI in Singapore, 497 gifted and non-gifted high-school chemistry students provided data about the chemistry laboratory classroom environment, teacher–student interactions, and student attitudes towards chemistry (Quek, Wong & Fraser, 2005). In addition to contributing to support for the validity and reliability of the CLEI and QTI, the study revealed gender differences in student perceptions. In general, females hold a more favorable view of their classroom learning environment than their male counterparts (Goh & Fraser, 1998; Khoo & Fraser, 2008; Kim, Fisher & Fraser, 2000; Wong & Fraser, 1996).

2.2.2.8 Constructivist Learning Environment Survey (CLES)

Constructivist learning theory refers to the process by which interaction with an environment allows the acquisition and testing of knowledge on a first-hand basis. Individuals then use active negotiation and consensus building to make sense of the acquired knowledge. The original form of the CLES (Taylor & Fraser, 1991) provided valuable insights into classroom learning environments, yet was found to have a weakness with regard to the classroom environment in terms of cultural context. While psychometrically sound as demonstrated in a number of studies (Lucas & Roth, 1996; Roth & Bowen, 1995; Roth & Roychoudury, 1993, 1994), the connection of the first version of the CLES to constructivist reform was less than robust. A redesign effort was undertaken to take into account the effects of cultural myths on the teaching and learning roles of teachers and students (Taylor, 1996; Milne & Taylor, 1996). This led to a version of the CLES (Taylor, Fraser, & Fisher, 1997) that assesses the consistency with constructivist epistemology of a classroom's environment and provides feedback to inform teaching practice.

This redesign effort also led to a shift from traditional formats of learning environment questionnaires by making significant changes to both the content and format of the CLES. First, conceptually-complex wording was eschewed in favor of more direct wording and the deliberate reduction of negatively-worded items resulted in a conceptually-simple more-economical 30-item form of five six-item scales. Second, the traditional cyclic ordering of learning environment items was replaced by the grouping together of all items within a scale into a block with an easily interpreted title. Third, students' evaluation of their current classroom environment was encouraged by the prompt "in this science (mathematics) class" for each question (Taylor, Fraser & Fisher, 1997).

The CLES measures students' perceptions of the occurrence of the five key elements of a constructivist environment for developing a balance between teachers' and students' control of and contribution to their educative relationship. The five frequency response choices of Almost Always, Often, Sometimes, Seldom, and Almost Never are used with CLES items. The scales of the CLES are Personal Relevance, Uncertainty, Critical Voice, Shared Control, and Student Negotiation.

The CLES has been used in large-scale quantitative studies to confirm the reliability and factor structure of the five scales. For example, a sample of 1,600 students in 120 9–12 grade science classes in the Dallas Public School system used the CLES to evaluate science and mathematics education systemic reform aimed at promoting more constructivist methods in teaching and learning (Dryden & Fraser, 1996). The baseline data showed sound reliability and factor structure.

Using a modified form of the 30-item CLES with a sample of 1,079 students sample in North Texas, Nix, Fraser and Ledbetter (2005) added a comparative student component to evaluate an innovative teacher development program. This program was based on the Integrated Science Learning Environment (ISLE) in which students in 59 classrooms were able to assess the level of constructivism in their current classroom as compared with other classrooms and teachers in their school (referred to in the study as the comparative cases of THIS and OTHER). Support for the comparative version of the CLES was demonstrated in terms of the factor structure, internal consistency reliability, discriminant validity and ability to statistically differentiate between students in different classes.

Modified English and Spanish-language versions of the CLES and Test of Science Related Attitudes (TOSRA) were given to 739 students in Miami, Florida students in grades K–3 as part of an action research project (Peiro & Fraser, 2009). The study, which in part investigated the changes in student perceptions of their classroom environment, understanding of science topics, and attitudes towards science, demonstrated support for the factor structure and internal consistency reliability of the CLES. This study marks the continuation of cross-cultural inclusion of important learning environment instruments.

Other notable efforts in this area were made by Kim and her colleagues in Korea. First, there was the translation of the Science Laboratory Environment Inventory (SLEI) in 1995–1997 and then the translation of the CLES, QTI, and WIHIC into the Korean language (Kim, Fisher & Fraser, 1999, 2000). The work in translation was especially important in this instance because learning environment research is closely linked in Korea with curriculum development.

The CLES was translated into Mandarin for a cross-national study of junior high school science classes involving 1879 students in Taiwan and 1081 students in Australia (Aldridge, Fraser, Taylor & Chen, 2000). As well as providing further cross-validation of the CLES in two languages in two countries, students in Australia were found to perceive higher levels of classroom constructivism than students in Taiwan.

In South Africa, Aldridge, Fraser and Sebela (2004) adapted the English version of the CLES and cross-validated it with 1864 students in 43 classes. The teachers of these classes used the CLES in successful and not-so-successful attempts to change their classroom learning environments.

2.2.2.9 What Is Happening In this Class? (WIHIC)

The What Is Happening In this Class? (WIHIC) questionnaire is the most widely-used learning environment questionnaire around the world today. It formed the basis on which the questionnaire used in my study (namely, the Technology-Rich Outcomes-Focussed Learning Environment Inventory, TROFLEI) was built. For these reasons, literature related to the WIHIC is reviewed comprehensively in this subsection, including both the history and the contributions of the WIHIC.

Although a variety of learning environment instruments made significant inroads into the understanding of classroom socio-psychological climate, there was a need for a single instrument that could draw together the best elements of the previous questionnaires. The WIHIC incorporates scales from earlier studies which had demonstrated their value in predicting learning outcomes as well as scales for measuring issues of growing social importance such as equity. The WIHIC was constructed by Fraser, Fisher and McRobbie (1996).

The original form of the WIHIC was a 90-item, nine-scale instrument that was evaluated by statistical analysis of data from 355 junior highs-school science students (Fraser, Fisher & McRobbie, 1996). The analysis also included in-depth students' interviews about their broad views about their classroom environments, as well as their views concerning the wording of questionnaire items. The 90-item instrument was pared down to 56 items in seven scales, which were then expanded to 80 items in eight scales for a second field test in junior high-school classes in Australia and Taiwan. An English version of the WIHIC was administered to 1,081 students in 50 classes in Australia, while a Chinese version, after careful translation and back translation, was administered to 1,879 students in 50 classes in Taiwan. The result was a finely-tuned version of the WIHIC that contains seven eight-item scales (Aldridge, Fraser & Huang, 1999) that has demonstrated good factorial validity and internal consistency reliability in many studies reviewed below.

A comprehensive cross-national validation of the WIHIC involved a sample of 3,980 high-school students in Australia, the UK, and Canada demonstrated the "wide international applicability of the WIHIC as a valid measure of classroom psychosocial environment' (Dorman, 2003, p. 231). In a follow-up study, Dorman (2008) used multitrait–multimethod modeling to generate further evidence supporting the validity of actual and preferred forms of the WIHIC.

The WIHIC also has been administered to 1474 high-school biology students in Turkey in a study of gender and grade-level differences in students' perceptions of their learning environments. Girls' scores on seven of the WIHIC scales were significantly higher than the boys' scores.

The extensiveness of past research with the WIHIC is illustrated in Table 2.2 that summarises the details of 22 studies involving the use of the WIHIC in six languages (English, Mandarin, Indonesian, Korean, Arabic, and Spanish) in many countries (Australia, the USA, Canada, the UK, Taiwan, Indonesia, Singapore, India, Korea, South Africa and the UAE). This table confirms that the WIHIC is robust in terms of its reliability, validity, and usefulness with samples from a variety of grade levels and subject areas in many different countries.

The list of 22 studies in Table 2.2 show the WIHIC's versatility as a psychosocial assessment tool as well as its international validity. The table lists the authors, the location, the language used, and the size and composition of the sample for each study. It is noteworthy that every study supported the WIHIC's factorial validity and internal consistency reliability. The final two columns of Table 2.2 indicate whether relationships between student outcomes and classroom environment were found, as well as identifying the specific outcomes involved.

The first four studies involved the WIHIC in multi-national, multi-language applications. A two-language study in Australia and Taiwan (Aldridge & Fraser, 2000) combined quantitative and qualitative methods including in-depth interviews that helped make sense of classroom environments. A three-country study in Australia, the UK and Canada in the English language (Dorman, 2003) validated the WIHIC's international applicability as a measure of psychosocial environment by substantiating factor structures for the three grouping variables of country, grade level, and student gender. A two-language, two-country study in Australia and Indonesia (Fraser, Aldridge & Adolphe, 2010) demonstrated measureable differences based on gender. Another two-country study in Australia and Canada in English (Zandvliet & Fraser, 2005) combined measurement of the psychosocial learning environment with an evaluation of the physical classroom environment via observation and in-depth interviews to provide insight into implementing technology into teaching and in the classroom.

The next group of five studies were conducted in English in four different countries. In Singapore (Chionh & Fraser, 2009), a large study of 2310 grade 10 students demonstrated a strong association between better examination scores in classrooms with more student cohesiveness. Also, in a Singaporean study of 250 adults taking computer education classes (Khoo & Fraser, 2008), male students perceived more support and involvement but less equity. In a study in India (Koul & Fisher, 2005), the use of the WIHIC and the QTI showed that student perceptions of their classroom environment varied with their cultural background. In Australia, use of the WIHIC demonstrated an increase in Type I error rates as the intraclass correlation increases, as well as providing a multitrait–multimethod modeling validation of actual and preferred versions (Dorman, 2008). Finally, when the WIHIC was used for the first time in a learning environment study in South Africa, discrepancies between actual and preferred learning environment formed the basis of an intensive, 12-week intervention to inform and improve teaching practice (Aldridge, Fraser & Ntuli, 2009). Although this study is mentioned as an English-language instrument, an IsiZulu version of the WIHIC also was cross-validated as part of the project.

The next two studies, the tenth and eleventh in Table 2.2, show that the WIHIC has been used in Korea in the Korean language and in Indonesia in the Indonesian language. In Korea, the WIHIC was once again paired with the QTI to demonstrate gender differences in classroom environment perceptions, and to suggest that students could benefit from more teacher support and peer cooperation (Kim, Fisher, & Fraser, 2000). In Indonesia, amongst other purposes, the WIHIC was used to show differences in the actual and preferred classroom environments based upon whether the students were in rural, suburban or urban schools. Urban students perceived less support and more cooperation than did their suburban counterparts (Wahyudi & Treagust, 2004).

The twelfth and thirteenth studies used an Arabic translation of the WIHIC in the United Arab Emirates. In an Arabic and English field test, the WIHIC demonstrated sound factorial validity and internal consistency reliability, and revealed that the students preferred a more positive classroom environment when their actual and preferred perceptions were compared (MacLeod & Fraser, 2010). A study involving WIHIC, enjoyment and academic efficacy scales showed that classroom games were successful for improving learning environments (Afari et al., 2013).

Table 2.2 Details of 22 Past Studies Involving the Use of the WIHIC

Reference(s)	Country(ies)	Language(s)	Sample(s)	Factorial Validity & Reliability	Associations with Environment for:	Unique Contributions
Aldridge, Fraser & Huang (1999); Aldridge & Fraser (2000)	Australia Taiwan	English Mandarin	1081 (Australia) & 1879 (Taiwan) junior high science students in 50 classes	✓	Enjoyment	Mandarin translation Combined quantitative and qualitative methods
Dorman (2003)	Australia UK Canada	English	3980 high school students	✓	NA	Confirmatory factor analysis substantiated invariant structure across countries, grade levels & sexes
Fraser, Aldridge & Adolphe (2010)	Australia Indonesia	English Indonesian	567 students (Australia) and 594 students (Indonesia) in 18 secondary science classes	✓	Several attitude scales	Differences were found between countries and sexes
Zandvliet & Fraser (2004 2005)	Australia Canada	English	1404 students in 81 networked classes	✓	Satisfaction	Involved both physical (ergonomic) and psychosocial environments
Chionh & Fraser (2009)	Singapore	English	2310 grade 10 geography & mathematics students	✓	Achievement Attitudes Self-esteem	Differences between geography & mathematics classroom environments were smaller than between actual & preferred environments.
Khoo & Fraser (2008)	Singapore	English	250 working adults attending computer education courses	✓	Satisfaction	Adult population Males perceived more trainer support & involvement but less equity
Koul & Fisher (2005)	India	English	1021 science students in 31 classes	✓	NA	Differences in classroom environment according to cultural background
Dorman (2008)	Australia	English	978 secondary school students	✓	NA	Multitrait–multimethod modelling validated actual and preferred forms

Table 2.2 (continued)

Reference(s)	Country(ies)	Language(s)	Sample(s)	Factorial Validity & Reliability	Associations with Environment for:	Unique Contributions
Aldridge, Fraser & Ntuli (2009)	South Africa	English	1077 grade 4–7 students	✓	NA	Preservice teachers undertaking a distance-education program used environment assessments to improve teaching practices
Kim, Fisher & Fraser (2000)	Korea	Korean	543 grade 8 science students in 12 schools	✓	Attitudes	Korean translation Sex differences in WIHIC scores
Wahyudi & Treagust (2004)	Indonesian	Indonesian	1400 lower-secondary science students in 16 schools	✓	NA	Indonesian translation Urban students perceived greater cooperation & less teacher support than suburban students
MacLeod & Fraser (2010)	UAE	Arabic	763 college students in 82 classes	✓	NA	Arabic translation Students preferred a more positive actual environment
Afari et al. (2013)	UAE	Arabic	352 college students in 33 classes	✓	Enjoyment Academic efficacy	Arabic translation Use of games promoted a positive classroom environment
den Brok et al. (2006)	California, USA	English	665 middle-school science students in 11 schools	✓	NA	Girls perceived the environment more favorably.
Martin-Dunlop & Fraser (2008)	California, USA	English	525 female university science students in 27 classes	✓	Attitude	Very large increases in learning environment scores for an innovative course
Ogbuehi & Fraser (2007)	California, USA	English	661 middle-school mathematics students	✓	Two attitude scales	Used 3 WIHIC & 3 CLES scales Innovative teaching strategies promoted task orientation.

Table 2.2 (continued)

Reference(s)	Country(ies)	Language(s)	Sample(s)	Factorial Validity & Reliability	Associations with Environment for:	Unique Contributions
Taylor & Fraser (2013)	California, USA	English	745 high-school mathematics students in 34 classes	✓	Anxiety	Involved mathematics anxiety Females perceived the environment more favorably
Wolf & Fraser (2008)	New York, USA	English	1434 middle-school science students in 71 classes	✓	Attitudes Achievement	Inquiry-based laboratory activities promoted cohesiveness & were differentially effective for males and females
Pickett & Fraser (2009)	Florida, USA	English	573 grade 3–5 students	✓	NA	Monitoring program for beginning teachers was evaluated in terms of changes in learning environment in teachers' school classrooms.
Allen & Fraser (2007)	Florida, USA	English Spanish	120 parents and 520 grade 4 & 5 students	✓	Attitudes Achievement	Involved both parents and students Actual–preferred differences were larger for parents than students.
Robinson & Fraser (2013)	Florida, USA	English Spanish	78 parents and 172 kindergarten science students	✓	Achievement Attitudes	Kindergarten level Involved parents Spanish translation Relative to students, parents perceived a more favorable environment but preferred a less favorable environment.
Helding & Fraser (2013)	Florida, USA	English Spanish	924 students in 38 grade 8 & 10 science classes	✓	Attitudes Achievement	Spanish translation Students of NBC teachers had more favourable classroom environment perceptions

Based on Fraser (2012)

The next nine studies using the WIHIC in Table 2.2 were all based in the United States. In California, the WIHIC was used to investigate factors that influence students' perceptions of their learning environment. Data from 665 middle-school science students in 11 Californian schools indicated that a variable that had a consistent effect on student perceptions was student gender, with girls perceiving their learning environment more positively than boys (den Brok et al., 2006). In a study with a sample of 525 female students in 27 classes in an urban Californian university, statistically significant and large improvements in learning environment and attitude scores were reported for students experiencing an innovative, highly-supportive classroom approach (Martin-Dunlop & Fraser, 2008). In another study of innovative teaching strategies, modified forms of the Constructivist Learning Environment Survey (CLES), What Is Happening In this Class? (WIHIC), and Test of Mathematics Related Attitudes (TOMRA) were administered to a sample of 661 middle-school students from 22 classrooms in four inner-city schools. Student responses supported the efficacy of innovative teaching methods with regards to learning environment and attitudes towards mathematics, especially Task Orientation (Ogbuehi & Fraser, 2007). For the final Californian study of Table 2.2 involving a sample of 745 high-school students in 34 classes, females perceived their classroom environments more favourably and there were associations between the learning environments and student anxiety (Taylor & Fraser, 2013).

In New York, the WIHIC was used to evaluate the perceptions of 1434 middle-school science students in 71 classes towards inquiry-based learning activities (Wolf & Fraser, 2008). Using inquiry-based instruction for a limited number of lessons had a positive impact on students' classroom environment perceptions and attitudes towards learning science, and it proved to be differentially effective for male and female students.

The next four studies, the 19th to 22nd in Table 2.2, took place in the state of Florida. Pickett and Fraser (2009, 2010) used the WIHIC with a sample of 573 grades 3–5 students to monitor changes in the school classroom environments of teachers involved in a beginning teacher mentoring program. Allen and Fraser (2007) used the WIHIC with a sample of 120 parents and 520 elementary students in grades 4 and 5 to investigate actual and preferred classroom environment perceptions;

actual–preferred differences were larger for parents than students. Robinson and Fraser (2013) used the WIHIC with a sample of 78 parents along with 172 kindergarten students to reveal that, while parents perceived a more favorable classroom environment, they preferred a less favourable one. Helding and Fraser (2013) reported that, for a sample of 924 students in 34 grade 8 and 10 science classes, students taught by National Board Certified Teachers had more favorable perceptions of their classroom environment (NBCT, 2000, 2001).

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

Outcomes-focused education centers the educational experience on what students should be able to do upon successfully completing that experience. This philosophy of outcomes-focused education was stated by Spady (1994, p. 1) as “starting with a clear picture of what is important for students to be able to do, then organizing the curriculum instruction, and assessment to make sure this learning ultimately happens”. Many countries throughout the world have used the model of outcomes-focused education for reform under a variety of names, including the United Kingdom as competency-based curriculum (Faris, 1998), New Zealand (Bell, Jones, & Carr, 1995), Canada (Hopkins, 2002), South Africa (Botha, 2002), and the USA in general as performance-based education (Evans & King, 1994). In the state of Florida, in particular, this approach is known as competency-based curriculum, as well as the impending shift to Common Core in the United States (Fletcher, 2010). While the consensus is that outcomes-focused education is a means to prepare students for the 21st Century global economy and workplace, much research remains to be undertaken to move this consensus from the realm of opinion to that of evidence (Aldridge & Fraser, 2008).

As countries around the world work to meet the demands of a 21st Century global economy (Education Commission of the States, 1995; Kerka, 1998), much attention is given to the educational model that will best prepare students for the these demands. The natural tendency is to focus on student achievement as an ‘outcomes focus’, while at the same time providing increasingly individualized educational plans. An effective system which provides an achievement guarantee is very difficult to attain (Aldridge, Fraser & Fisher, 2003), but it is becoming easier to provide individualized learning plans by using Information Communications Technology (ICT). ICT can provide the teacher with a method to accommodate diverse learning styles and paces, as well as to enhance students' outcomes (Khine & Fisher, 2001, 2002).

As the move to incorporate ICT into classroom teaching and learning environments continues to require large financial investment in equipment, networks and training, the need to evaluate its effectiveness also continues to grow. One promising way to evaluate the 'effects and affects' of the integration of ICTs into school classrooms (Zandvliet, 2003) involves the field of learning environment. For an instrument to evaluate the effectiveness of this new, technology-supported teaching and learning environment, the WIHIC was a logical starting point for my study.

The literature supporting the successful use of the WIHIC is voluminous and the literature supporting the TROFLEI, while not as large, is growing. The TROFLEI draws upon all seven of the WIHIC scales of Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation and Equity. In addition to these, three new scales were added: Differentiation, Computer Usage, and Young Adult Ethos. These scales were added to provide relevance to ICT classroom use and outcomes-focused learning environments. The TROFLEI originally contained 80 items including 8 items for each of the 10 scales but, after field testing and validation, modifications were made while retaining the original 10 scales (Aldridge & Fraser, 2008). To reduce student confusion, the TROFLEI was arranged with all items belonging to a particular scale placed in a single block rather than arranged randomly. The version of the TROFLEI used in my study was a slightly modified 80-item version.

A study drawing upon data from 2317 Australian students in 166 classrooms (Aldridge & Fraser, 2008) investigated the factorial validity and internal consistency reliability of the TROFLEI. This study showed similarly strong factorial validity and internal consistency indices for the TROFLEI as were reported in previous studies that used the WIHIC (Aldridge & Fraser, 2000; Chionh & Fraser, 2008, Fraser &

Raafluab, 2013). Also Aldridge, Dorman and Fraser (2004) used multitrait–multimethod modeling with TROFLEI responses from a sample of 1249 students, of whom 772 were from Western Australia and 477 were from Tasmania. When the 10 TROFLEI scales were used as traits and the actual and preferred forms of the instrument as methods, the results supported the TROFLEI's construct validity and sound psychometric properties, as well as indicating that the actual and preferred forms share a common structure.

The TROFLEI recently was translated, validated and used in Turkey with a sample of 980 grade 9–12 students, as well as an English-language version being used with 130 grade 9–12 students in the USA (Welch, Cakir, Peterson & Ray, 2012). For both actual preferred forms and for both Turkey and USA, the TROFLEI exhibited sound reliability and factorial validity when confirmatory factor analysis was used. In New Zealand, Koul, Fisher and Shaw (2011) used the TROFLEI with a sample of 1027 high-school students from 30 classes. As well as cross-validating the TROFLEI in both its actual and preferred forms, this study revealed sex and grade-level differences in perceptions, as well as associations between students' attitudes and their classroom environment perceptions.

2.2.2.11 Other Instruments Including COLES

Several other instruments that measure the learning environment in the context of computers and technology were considered for this study, including the Constructivist Multimedia Learning Environment Survey (Maor, 1999), Computer Classroom Environment Inventory, Computer Laboratory Environment Inventory (Maor & Fraser, 1996; Newby & Fisher, 1997), and Distance Education Learning Environment Survey (Walker & Fraser, 2005). However, I chose the TROFLEI because the research focus was the learning environment of a traditional classroom supplemented by computer resources, not a computer laboratory environment.

The last questionnaire listed in Table 2.1 is the Constructivist-Oriented Learning Environment Survey (COLES), which incorporates numerous scales from the WIHIC into an instrument that is designed to provide feedback as a basis for reflection in teacher action research. In constructing the COLES, Aldridge, Fraser, Bell and Dorman (2012) were especially conscious of the omission in all existing classroom environment questionnaire of important aspects related to the assessment of student learning. The COLES incorporates six of the WIHIC's seven scales (namely, Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Cooperation and Equity), while omitting the WIHIC's Investigation scale. Like the TROFLEI, the COLES also includes the scales of Differentiation and Young Adult Ethos. In addition, the COLES includes the Personal Relevance scale from the CLES (the extent to which learning activities are relevant to the student's everyday out-of-school experiences). The two new COLES scales related to assessment are Formative Assessment (the extent to which students feel that the assessment tasks given to them make a positive contribution to their learning) and Assessment Criteria (the extent to which assessment criteria are explicit so that the basis for judgments is clear and public).

For a sample of 2043 grade 11 and 12 students from 147 classes in nine schools in Western Australia, data analysis supported the sound factorial validity and internal consistency reliability of both actual and preferred versions of the COLES. A noteworthy methodological feature of this study was that the Rasch model was used to convert data collected using a frequency response scale into interval data suitable for parametric analyses. When analyses were performed separately for raw scores and Rasch scores, Aldridge et al. (2012) found that the differences between the validity results were negligible. The COLES has been used successfully by teachers in action research aimed at improving their classroom environments (Aldridge et al., 2012).

Fisher and Waldrip (1997, 1999) developed the Cultural Learning Environment Questionnaire (CLEQ) to assess the following culturally-sensitive factors in students' learning environment: Gender Equity, Collaboration, Deference, Competition, Teacher Authority, Modelling and Congruence. This questionnaire was used later in modified form to investigate the beliefs of 475 trainee teachers enrolled at the University of Brunei Darussalam (Dhindsa & Fraser, 2004) and to identify sex and age differences in the perceptions of 912 grade 8 students in Brunei (Dhindsa & Fraser, 2011).

Acknowledging that social conditions affect both the learning and the experience within a learning environment, a robust instrument that focuses on students' perceptions of environmental education in place-based educational settings was designed and validated. The development of this instrument, with the help of input from environmental educators, involved qualitative data gathered from focus groups concerning the factors that teachers considered most important to environmental learning. The result was eight scales that were developed and/or modified from earlier environment surveys to become the Place-Based Learning and Constructivist Environment Survey (PLACES) for the evaluation of student perceptions of the learning environment in place-based and environmental education settings (Zandvliet, 2012). Later, PLACES was adapted for elementary-school students to form the SMILES for assessing eight scales (Relevance/Integration, Critical Voice, Student Negotiation, Group Cohesiveness, Student Involvement, Shared Control, Open-Endedness and Environmental Interaction) and validated with 169 grade 4–7 students in British Columbia (Zandvliet, 2013).

2.2.3 Past Research with Learning Environment Instruments

The considerable past research involving the use of learning environment questionnaires has been comprehensively reviewed by Fraser (1998, 2012, 2014) and in books edited by Khine and Fisher (2003) and Fisher and Khine (2006). A few of these past lines of research are considered below: improving classroom environments (Section 2.2.3.1), cross-national studies (Section 2.2.3.2), evaluation of educational innovations (Section 2.2.3.3) and associations between learning environment and student outcomes (Section 2.2.3.4).

2.2.3.1 Improving Classroom Environments

Teachers have used feedback information based on assessment of students' actual and preferred classroom learning environment as a basis for guiding practical improvements in their classroom environments. The five-step procedure used in past research involves (1) assessment, (2) feedback, (3) reflection and discussion, (4) intervention and (5) reassessment (Fraser, 1981b). This technique has been applied successfully in case studies in Australia (Aldridge & Fraser, 2008; Fraser & Fisher, 1986; Yarrow, Millwater & Fraser, 1997), South Africa (Aldridge, Fraser & Sebela, 2004) and the USA (Sinclair & Fraser, 2002). In a recent study, teachers made use of the COLES in action research that successfully led to improvements in their classroom learning environments (Aldridge, Fraser, Bell & Dorman, 2012).

2.2.3.2 Cross-National Studies

Aldridge, Fraser and Huang (1999) reported a cross-national learning environment study involving six Australian and seven Taiwanese science education researchers in working together. The WIHIC was administered to 50 junior high-school science classes in each of Taiwan (1879 students) and Australia (1081 students). An English version of the questionnaire was translated into Chinese, followed by an independent back translation of the Chinese version into English by team members who were not involved in the original translation. Qualitative data, involving interviews with teachers and students and classroom observations, were collected to complement the quantitative information and to clarify reasons for patterns and differences in the mean scores in each country.

The scales of Involvement and Equity had the largest differences in means between the two countries, with Australian students perceiving each scale more positively than students from Taiwan. Data from the questionnaires were used to guide the collection of qualitative data. Student responses to individual items were used to form an interview schedule that was used to clarify whether items had been interpreted consistently by students and to help to explain differences in questionnaire scale means between countries. Classrooms were selected for observations on the basis of the questionnaire data, and specific scales formed the focus for observations in these classrooms. The qualitative data provided valuable insights into the perceptions of students in each of the countries, helped to explain some of the differences in the means between countries, and highlighted the need for caution when interpreting differences between the questionnaire results from two countries with cultural differences (Aldridge & Fraser, 2000).

Similar cross-national research involving the use of the CLES in Taiwan and Australia was reported by Aldridge, Fraser, Taylor and Chen (2000), whereas cross-national research in Indonesia and Australia was reported by Fraser, Aldridge and Adolphe (2010).

2.2.3.3 Evaluation of Educational Innovations

One of the past applications of classroom environment assessments that is directly relevant to my study is their use as criteria of effectiveness in the evaluation of educational innovations or new educational programs. The significance of these past evaluation studies is that classroom environment variables differentiated revealingly by between educational alternatives even when outcome measures showed small differences.

Nix, Fraser and Ledbetter (2005) used the CLES in their evaluation of an innovative teacher development program among 445 students in 25 classes in Texas. The students of teachers who had experienced this professional development program perceived their classrooms as having appreciably higher levels of Personal Relevance and Uncertainty relative to comparison classes.

Lightburn and Fraser (2007) used the SLEI among 761 high-school biology students in Florida in an evaluation of the effectiveness of using anthropometric activities. Relative to a comparison group, the anthropometric group had higher scores on some SLEI and attitude scales.

Mink and Fraser (2005) evaluated a program that integrates mathematics with children’s literature in K–5 classes in a small-scale study of 120 grade 5 mathematics students in Florida. This program is called SMILE (Science and Mathematics Integrated with Literature Experiences). The use of the MCI suggested the positive impact of the SMILE program in that congruence between students’ actual and preferred classrooms was achieved.

In a further example, Spinner and Fraser (2005) evaluated the effectiveness of the Class Banking System (CBS) in terms of the students’ mathematical concept development, attitudes towards mathematics, and perceived classroom environment on several scales drawn from the CLES and ICEQ. Two samples consisted of 53 and

66 elementary mathematics students in Florida. Compared with a control group, CBS students experienced more favorable changes in classroom environment.

Aldridge and Fraser (2008) used the TROFLEI in evaluating the success of an innovative new school in Western Australia over four years. Analyses of data from over a thousand students revealed statistically significant changes of moderate magnitude (from 0.20 to 0.38 standard deviations) for seven of the TROFLEI's 10 scales during the time period.

In New York, Wolf and Fraser (2008) used the WIHIC in their evaluation of the efficacy of using inquiry-based laboratory activities with middle-school science students. Inquiry instruction was found to promote more Student Cohesiveness than non-inquiry approaches and to be differentially effective for male and female students.

In Singapore, Khoo and Fraser (2008) adapted the WIHIC for their evaluation of adult computer courses among a sample of 250 working adults. Generally students perceived their classroom environments positively, but males perceived significantly more Involvement whereas females perceived more Equity.

Martin-Dunlop and Fraser (2008) evaluated an innovative science course for preservice elementary teachers in a large urban university in California. The administration of selected WIHIC and SLEI scales to 525 females in 27 classes revealed very large differences of over 1.5 standard deviations on all scales between students' perceptions of the innovative course and previous courses.

2.2.3.4 Associations Between Learning Environment and Student Outcomes

The strongest tradition in past classroom environment research has involved investigating associations between students' outcomes and their perceptions of the nature of the learning environment (Fraser, 2012). These studies consistently have shown that student perceptions of classroom environment account for appreciable amounts of variance in students' cognitive and affective outcomes. One of the aims of my study involved investigating associations between classroom environment (assessed with the TROFLEI) and student attitudes to mathematics.

A comprehensive study in Singapore involved 2310 Grade 10 mathematics and geography students in responding to the WIHIC and measures of student attitudes and achievement (Chionh & Fraser, 2009). Better examination scores were found in classrooms with a higher level of student cohesiveness. As well, self-esteem and attitudes were more favorable in classrooms with more teacher support, task orientation and equity.

In an investigation of the associations between classroom environment and academic efficacy, a sample of 1055 Australian secondary mathematics students revealed significant associations between classroom efficacy and five scales of the WIHIC including Teacher Support, Involvement, Investigation, Task Orientation, and Equity (Dorman 2001).

In Brunei Darussalam, a sample of 1565 secondary mathematics students responded to the MCI. Statistically significant relationships were found between student satisfaction as an attitudinal outcome variable and the three learning environment scales of Cohesiveness, Difficulty, and Competitiveness (Majeed, Fraser & Aldridge, 2002).

In a study of 487 gifted and non-gifted secondary-school Singaporean chemistry students, data from the Chemistry Laboratory Environment Inventory (based on the SLEI) and the QTI revealed statistically significant associations between students' attitudes towards chemistry, the learning environment and chemistry teachers' interpersonal behavior (Quek, Wong & Fraser, 2005a). In another study involving 1592 Singaporean secondary-school students, associations were found between several attitude scales and the same learning environment instrument (Wong & Fraser, 1966; Wong, Young & Fraser, 1997).

Walberg's (1981) multi-factor psychological model of educational productivity incorporates the psychosocial learning environment. In this theory, learning is a function of student age; ability and motivation; quality and quantity of instruction; and the psychosocial environments of the home, the classroom, the peer group and the mass media. In the classroom context, this theoretically means that zero motivation or zero time for instruction results in zero learning. It is thus better to improve a factor that is the main hindrance to learning than to improve a factor that is already high. Fraser, Walberg, Welch and Hattie (1987) undertook extensive research syntheses involving correlations of learning with the factors in the model in order to make empirical probes of Walberg's (1981) model. Secondary analyses were also conducted with National Assessment of Educational Achievement data (Walberg, 1986) and National Assessment of Educational Progress data (Fraser et al., 1986; Walberg, Fraser & Welch, 1986). Classroom and school environments were found to be strong predictors of both achievement and attitudes even when a comprehensive set of other factors was held constant.

Fraser and Kahle (2007) investigated the effects of several types of environments on student outcomes using secondary analysis of a large database from a Statewide Systemic Initiative (SSI) in the USA. The study spanned three years and involved administering a questionnaire that assessed class, home and peer environments and student attitudes to nearly 7000 students in 392 middle-school science and mathematics classes in 200 different schools. Students also completed an achievement measure. Rasch analyses were conducted to compare across student cohorts and across schools. Findings confirmed the importance of extending research on classroom learning environments to include the learning environments of the home and peer group. All three environments accounted for statistically significant amounts of unique variance in student attitudes. However, only the class environment (defined in terms of the frequency of use of standards-based teaching practices) accounted for statistically significant amounts of unique variance in student achievement scores.

2.3 Attitudes to Mathematics: Test of Mathematics Related Attitudes (TOMRA)

Attitudes have been considered as a central concept in the field of psychology for a long time, with Allport (1935) noting that "this concept is probably the most distinctive and indispensable concept in contemporary American social psychology"

(p. 43). An attitude can be defined as “a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor” (Eagly & Chaiken, 1993, p. 1). Attitude can have: a cognitive component, which involves thoughts, beliefs, or ideas about an attitude object; an affective component which involves feelings or emotions that the attitude object evokes; and a behavioral component which involves a tendency or disposition to act in certain ways toward the attitude object (McGuire, 1969). Specifically in mathematics education, attitude is an emotional disposition toward mathematics, such as likes and dislikes of students, the enjoyment that they feel during lessons, and the preference that they have during mathematics instruction (Aiken, 2002).

One of the most widely-used instruments for assessing mathematics attitudes is the Fennema–Sherman Mathematics Attitude Scale which was developed initially for studying gender differences in attitudes towards mathematics (Fennema & Sherman, 1976). This instrument consists of the nine scales of Attitude Toward Success in Mathematics Scale, Mathematics as a Male Domain Scale, Mother Scale, Father Scale, Teacher Scale, Confidence in Learning Mathematics Scale, Mathematics Anxiety Scale, Effectance Motivation Scale in Mathematics, and Mathematics Usefulness Scale. Around the same time, Sandman (1980) developed the Mathematics Attitude Inventory to measure attitudes with the six scales of Value of Mathematics, Self-concept in Mathematics, Anxiety towards Mathematics, Enjoyment of Mathematics, Motivation in Mathematics, and Perceptions of Mathematics Teachers.

To measure students’ attitudes towards mathematics, my study made use of the Test of Mathematics Related Attitudes (TOMRA). Therefore this section reviews literature about the Test of Science Related Attitudes (TOSRA) (Fraser, 1981a), which was modified to form the Test of Mathematics Related Attitudes (TOMRA) for assessing students’ attitudes toward mathematics in my study.

Designed to measure secondary students’ attitudes towards science, the TOSRA distinguishes between seven separate and distinct science-related attitudes that are built upon Klopfer’s (1971) original six categories of attitudes: Social Implications of Science and Normality of Scientists, Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science, and Career Interest in Science. Klopfer's scheme combines the manifestation of favorable attitudes towards science and scientists, but the TOSRA has a separate measure for each, thus leading to a total of seven scales.

One advantage of the TOSRA is that it provides a profile of attitude scores over the category range and, while the results are difficult to interpret on an absolute scale, they can provide a comparative interpretation (Fraser, 1981a). The use of the TOSRA as a measure of affective outcomes can be effectively combined with measures of learning environment to provide useful criteria of effectiveness, as well as to permit investigation of associations between attitudes and classroom environment.

In science education, the measurement and investigation of students' attitudes have a long history, but continues as a contemporary interest internationally today (Kind & Barmby, 2011; Saleh & Khine, 2011; Tytler & Osborne, 2012). Kind, Jones and Barmby (2007) drew on the work of Munby (1983, 1997), Schibeci and McGaw (1981) and Osborne, Simons and Collins (2003) in identifying numerous important and long-standing problems related to many of the attitude scales developed in the past. Some of these include: the lack of clarity in the descriptions for the constructs to be measured; the combining of conceptually-different constructs to form one unidimensional scale; low reliability of measurement; and failure to address construct validity.

The widely-used Test of Science-Related Attitudes (TOSRA, Fraser, 1981a) was selected for use in this study because it overcomes most of the problems addressed by Kind, Jones and Barmby (2007) and Munby (1997). First, the TOSRA clearly defines each of the constructs to be measured by providing distinct subscales based on Klopfer's (1971) classification of students' attitudinal aims: attitude to science and scientists, attitude to inquiry, adoption of scientific attitudes, enjoyment of science learning experiences, interest in science, and interest in a career in science. These six constructs are clearly defined and each represents a different 'object' about which students are likely to form opinions. Second, the TOSRA does not combine conceptually-different constructs to form one scale. Third, past studies that have used the TOSRA provide strong evidence of its psychometric quality in terms of scale reliability. Fourth, each scale of the TOSRA has demonstrated unidimensionality and independence in past studies through factor analysis. When Munby investigated the adequacy of 56 attitude instruments using criteria similar to those described by Kind, Jones and Barmby (2007), he described TOSRA as "an exceptionally well developed scale" (Munby, 1983, p. 314).

Although the TOSRA was designed originally to assess students' attitudes specifically to the subject of science, various researchers have adapted it for other subjects. In particular, several researchers in the USA changed the word 'science' to 'mathematics' to form the Test of Mathematics Related Attitudes (TOMRA). Examples of studies that used TOMRA are Ogbuehi and Fraser's (1997) research in California and Spinner and Fraser's (2005) study in Florida. In Singapore, TOSRA was modified to form the Test of Chemistry Related Attitudes (TOCRA) and used it with 1592 final-year chemistry students (Wong & Fraser, 1996) and 497 tenth-grade chemistry students (Quek, Wong & Fraser, 2005). In Texas, Walker (2006) modified TOSRA to form the Test of Geography Related Attitudes (ToGRA) and validated it with 388 grade 9 geography students. In Florida, Adamski, Fraser and Peiro (2013) modified TOSRA to form the Test of Spanish Related Attitudes and used it with 223 grade 4–6 students learning Spanish.

The first validation of the TOSRA took place in 1977 (Fraser, 1981a) and involved both Australian and United States science students in grades 7–12. The TOSRA has been found to be valid and useful with large samples in many studies in countries such as Australia and Indonesia (Fraser, Aldridge & Adolphe, 2010), Singapore (Wong & Fraser, 1996) and Taiwan and Australia (Aldridge, Fraser, & Huang, 1999). As noted above, the adaptation of TOSRA for mathematics classes (namely, TOMRA) has been validated with mathematics students in Miami (Spinner & Fraser, 2005) and California (Ogbuehi & Fraser, 2007).

2.4 Mathematics Online Support Resources

Educational improvements since World War II have focused in large measure on either improving instructional materials for classroom use or providing teachers with training in the use of new instructional methods, but these efforts seldom have led to detectable, sustainable improvements (Ball & Cohen, 1999). With the beginning of widespread computer use in classrooms in the 1980s, the use of progressively more advanced hardware and software has been forecast to improve student achievement (Adams, Carlson & Hamm, 1990). The World Wide Web has become a popular instructional medium because of its accessibility and ability to display options, among other reasons, but the instructional effectiveness of online programs remains unproven (Alexander, 1995).

Because my study involved an evaluation of an online support resource called FCAT Explorer, this section is devoted to consideration of the evolution of the FCAT standardized achievement testing program in Florida, as well as the development and evaluation of FCAT Explorer and other online resources. The subsections below focus on statewide assessment in Florida (Section 2.4.1), computer-based instructional resources (Section 2.4.2), the development of FCAT Explorer (Section 2.4.3), FCAT Explorer itself (Section 2.4.4), and the effectiveness of technology-assisted instruction (Section 2.4.5).

2.4.1 Chronology of Florida Assessment

The current assessment scheme in Florida can be traced back to 1968 when the State Legislature instructed the Department of Education to improve educational effectiveness in Florida Schools. A plan was developed by the commissioner of education, and the resultant legislation, the Educational Accountability Act of 1971, called for the establishment of uniform state-wide educational objectives for each grade level and subject area including, but not limited to, reading, mathematics, and writing. With the publication of the influential A Nation at Risk (U.S. Department of Education, 1983), the next three decades saw a series of tests adopted and revised including the SSAT (1977), the SSAT–II (1978, 1981), the High School Competency

Test (HSCT) (1984), the Florida Writing Assessment Program (FWAP) (1992), and the Grade 10 Assessment Test (GTAT) (1992).

In 1991, new legislation called the School Improvement and Accountability Act set seven goals for the state's public education system, and this was accompanied by the Florida Commission on Education Reform and Accountability in the form of the Blueprint 2000 regarding the methodology for assessing student learning. Within that set of goals, goal number 3 contained 10 standards, the first four of which directly addressed improving student performance in reading, writing, mathematics and thinking skills. In 1995, the State Board of Florida Comprehensive Assessment Design (FCAD) outlined a design that called for students to be tested in reading, writing, mathematics, as well as creative and critical thinking skills. This led to the development of a set of standards defined as learning expectations in seven content areas including language arts, mathematics, science, social studies, health and physical education, foreign languages, and the arts. This set of learning expectations was adopted in 1997 as the Sunshine State Standards (SSS) that formed the basis for the Florida Comprehensive Assessment Test (FCAT). The design specification required assessments to measure achievement against the learning expectation standards across four grade groups: PreK–2, 3–5, 6–8, and 9–12. Over the next several years, the assessment instruments used up to that point were incorporated into the FCAT or replaced by it altogether. In 1999, the Florida State Legislature enacted the A+ Plan for Education (Florida Statutes Ch. 99.398) that expanded the grade bands to include grades 3–10 for reading and mathematics, and further defined the high school graduation requirement of a passing grade in Grade 10 SSS reading and mathematics.

Concurrent with the reform and assessment design that Florida was undertaking, the United States Congress proposed in 2001 and passed in 2002 a reauthorization of the Elementary and Secondary Education Act (ESEA) called the No Child Left Behind Act of 2001 (NCLB). The NCLB coupled standards-based education reform of high standards and measureable outcomes to those standards with provisions for actions to be taken if the standards were not achieved over time. Contrary to the widely-held belief that the NCLB created a national standard, the Act required states to create assessments in basic skills to be administered at specific grade levels in order to qualify for and receive federal education funds. NCLB required the assessment of all students in grades 3–8 in reading and mathematics. Florida had already enacted, as part of the A+ Plan, a state-wide series of assessments in those subjects along with others in grades 3–10. As a result, no change in content, development process, or administration was required in Florida.

Changes that were required stemmed from the consequences for not achieving the established assessment goals. The Florida Board of Education required schools to be assigned a grade based on annual performance, with scores ranging from A on the high end of the scale to F on the low end. School performance grades based upon the attainment of the higher FCAT grades or improvement by two letter grades or more led to granting of more autonomy and authority over the school's budget. Schools at the lower end of the scale, including the performance grade category of D or F, are eligible, in many cases, to receive assistance in the form of additional state and district personnel who provide curriculum and formative assessment guidance on an ongoing basis. If improvement in the performance grade category is not achieved after two years, then students attending that school are eligible to receive a state voucher which allows the funding allocated for that child's education to be transferred to a higher-performing school within the original school's same district. The high-stakes tests, then, through application of graduation requirements for the students, budget implications for schools, and attendance impact at public education institutions, brought considerable pressure for success at many different levels (Florida Department of Education, 2005).

2.4.2 Computer-Based Instructional Resources

One approach to creating a path to success on the FCAT in Florida was to turn to web-based educational software to provide a widely-available, uniformly-written test preparation tool for all students within the state. Researchers have examined the development of computer-based instructional and practice programs in terms of achievement on high-stakes tests such as the FCAT (McDonald & Hannafin, 2003; Wright, Barron & Kromry, 1999). With advancements in the presentation of materials and the availability of web-based design, instructional software provides learning opportunities for students in the school environment and home environment, and with smart ‘phones and tablets recently providing these same opportunities virtually anywhere.

In the design of instructional software, a number of key elements have been shown to be important. Learning abstract mathematical content can be a challenge to students, and research has shown that applying mathematics via real-life situations can enhance critical thinking and mathematical reasoning while improving retention and transfer of learning (Schoenfeld, 1992; Verzoni, 1997). Other key elements to consider in the design characteristics are feedback (Khine, 1996) and interactivity as a contributor to motivation (Bolliger & Martindale, 2004; Hawkes & Dennis, 2003). Of great importance in the design and even the choice of the instructional program is the budgetary element because such programs can be expensive to purchase or license and be complicated to maintain and manage (Fahy, 2000; Kim & Sharp, 2000).

2.4.3 FCAT Explorer Development

The FCAT Explorer was created by Infinity Software of Tallahassee Florida, a consulting and software development services company founded in 1994, as part of a $13 million software development project commissioned by the State of Florida (Folleck, 2005). The online program was started in 2000 by the Florida State Department of Education (FLDOE) to offer a grade-specific group of practice problems in both reading and mathematics to all Grade 3–10 public school students in the state (over 1.5 million students). It also provides a parent and family guide for reading in grades 3, 4, 6, 8 and 10 and for mathematics in grades 5, 8 and 10.

The design of the program was based upon cognitive learning theory for instructional design (Dick & Carey, 1996) and incorporated learner motivation elements based upon Keller’s ARCS model (Keller, 1987; Naime-Diefenbach, 1991). The ARCS model denotes Attention, Relevance, Confidence and Satisfaction.

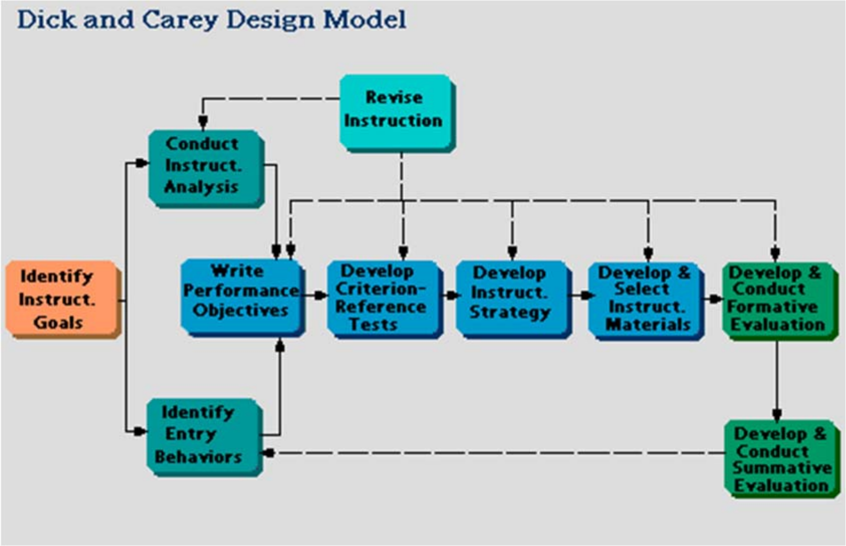


Figure 2.1 Dick and Carey (1996) Instructional Design Model

The nine components in an iterative cycle according to the Dick, Carey and Carey model in Figure 2.1 include:

1. Identify the instructional goals
2. Conduct an instructional analysis of what is learned and how it is learned
3. Identify entry behaviors
4. Write performance objectives
5. Develop criterion-referenced tests
6. Develop instructional strategy
7. Develop and select instructional materials
8. Develop and conduct formative evaluation
9. Revise instruction based upon formative evaluation results.

Other elements taken into consideration in the design of the FCAT Explorer program from the ARCS model (Keller, 1987) include the study of human motivation and the analysis of the target audience, with the aim of providing an opportunity for building confidence and satisfaction. In other words, the ARCS model involves what makes students want to learn. Combining multi-step continuous evaluation, motivational approaches, and appropriate content for the grade level (based on the criteria established by the state) created the foundation upon which the FCAT Explorer was built.

2.4.4 FCAT Explorer Program

The mathematics program of FCAT Explorer has three different levels that provide benchmark-specific problems for grades 5, 8 and 10. The practice items provided at each of these grade levels allow answers to be given in either a multiple-choice format or using a fill-in grid referred to as a gridded response item. The mathematics at each grade level is aligned to the appropriate benchmarks, namely, the Sunshine State Standards until 2007 and then the Next Generation Sunshine State Standards until 2014.

Also, FCAT Explorer provides Correct Answer Explanation (CAE), that provides students with a simple explanation of the problem and its related concepts when students answer the question correctly. If the student does not answer the question correctly, the program provides a hint and a second chance to apply the hint. A student who is unsuccessful at the second attempt is moved to the next problem but the missed problem is placed on a challenge list. Figure 2.2 shows the FCAT Explorer Problem Presentation Process. In order to complete the section, the student must answer the questions in the challenge list. The program also provides the student with access to reference materials. Because the program is provided as an online resource, the type, age, and operating system of the computer used to access it is not an issue.

Teachers can access feedback about performance results for their students. Performance data can be displayed by student or by class. The FCAT Explorer is promoted by the FLDOE and is available in school districts throughout the state.

Within the context of the Dick and Carey Model, as well as the ARCS model from Keller, the FCAT Explorer was designed with student motivation as a key element. Additionally, the content of the problem is designed to meet the criteria specified by the FLDOE for the 8th grade mathematics standards, and is contextualized within a real-world situation so as to provide connections that go beyond the computational practice approach. This section presents problems from the student point of view, including a series of incorrect answers, and shows what the student experiences in those circumstances.

Figure 2.3 displays a problem posed within the context of a ski jumper at the Winter Olympic Games. There is a brief explanation of the ski jumping sport which is followed by a problem exposition involving similar triangles. The correct mathematical answer helps the skier to achieve a longer flight.

If the student enters an incorrect answer, the screen shown in Figure 2.4 provides hints on how to approach the problem and a link to a definition of similar triangles. When the student clicks the Try Again button, the problem is once again presented exactly as shown in Figure 2.3. If the student once again enters an incorrect answer, a second screen with a Correct Answer Explanation (CAE) appears as shown in Figure 2.5. There is no reward graphic on this screen.

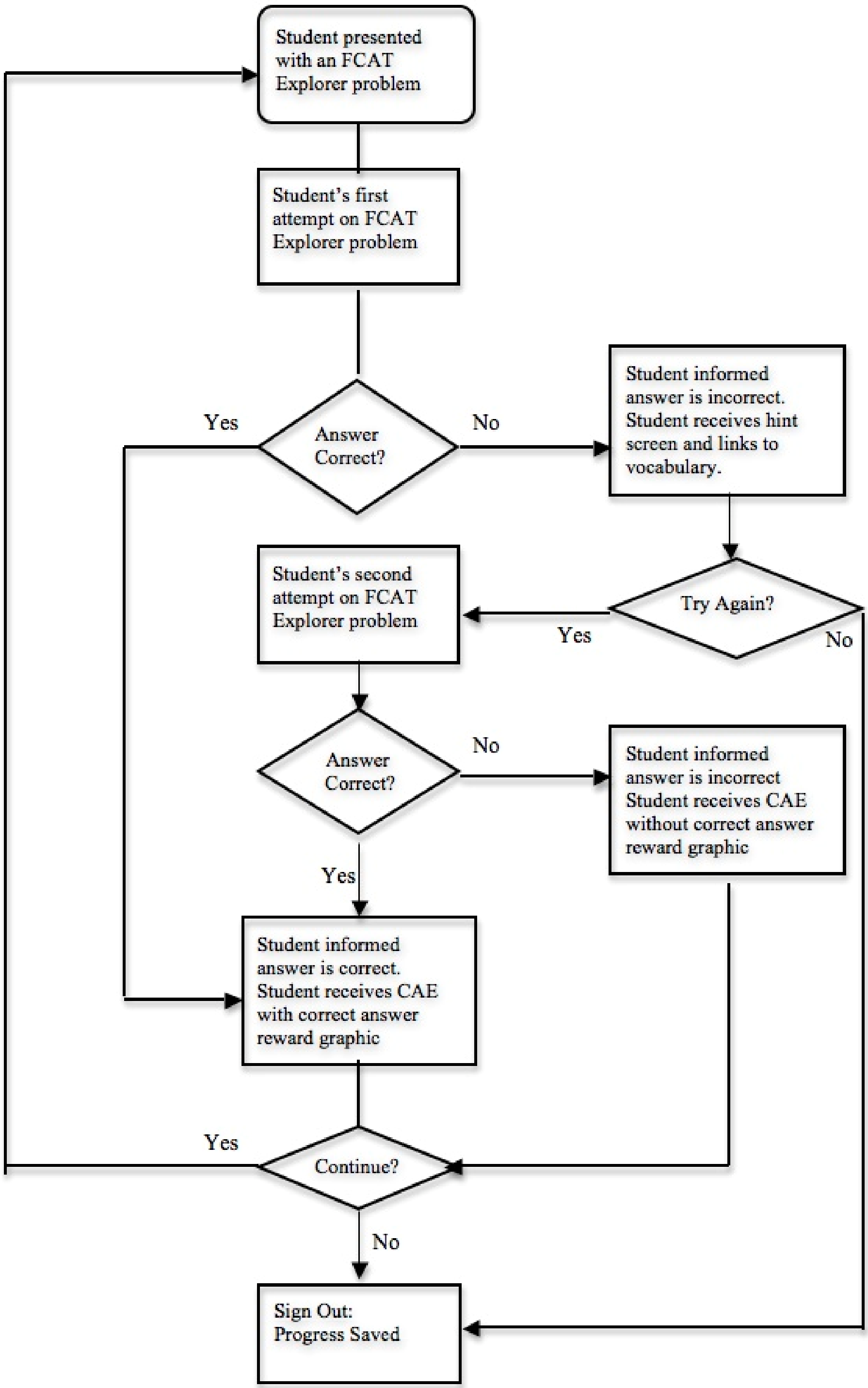
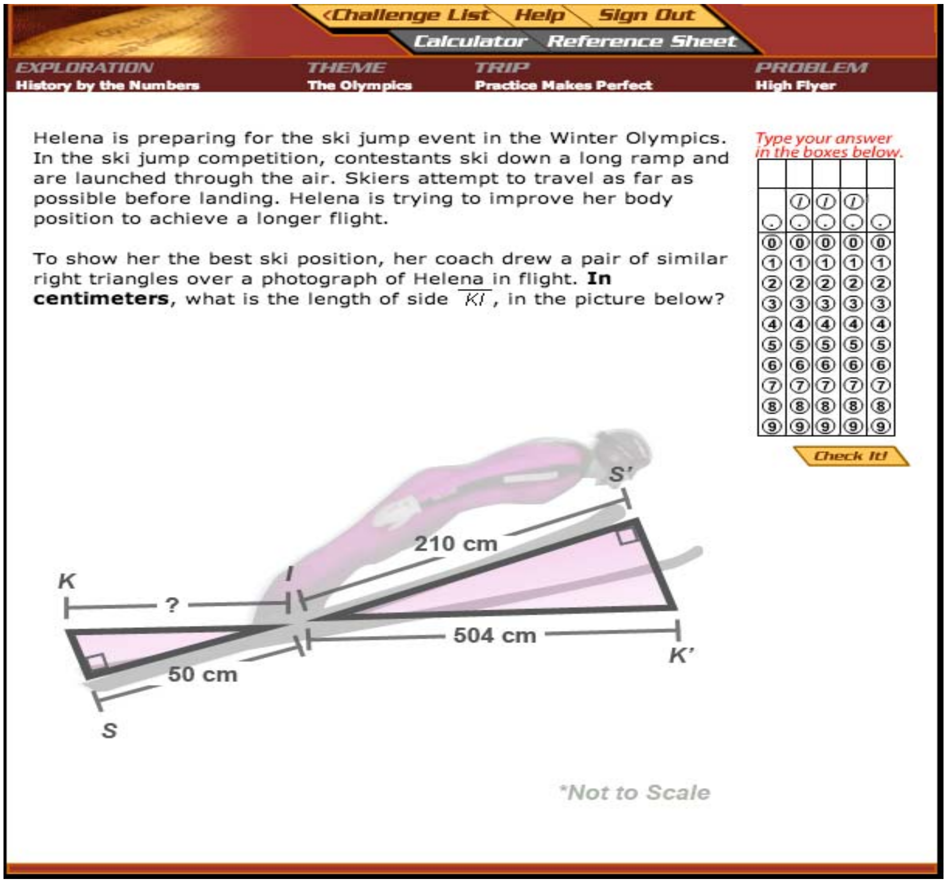


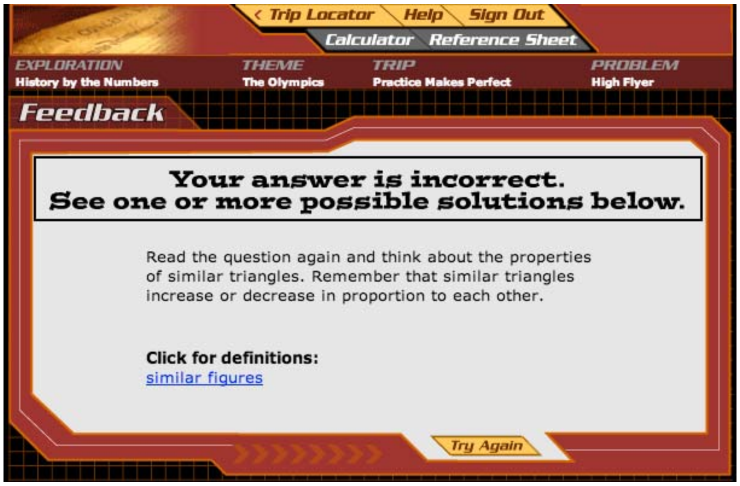
Figure 2.2 FCAT Explorer Problem Presentation Process



Helena is preparing for the ski jump event in the Winter Olympics. In the ski jump competition, contestants ski down a long ramp and are launched through the air. Skiers attempt to travel as far as possible before landing. Helena is trying to improve her body position to achieve a longer flight.

To show her the best ski position, her coach drew a pair of similar right triangles over a photograph of Helena in flight. **In centimeters**, what is the length of side $\overline{KI}$, in the picture below?

Figure 2.3 Ski Jumper Problem

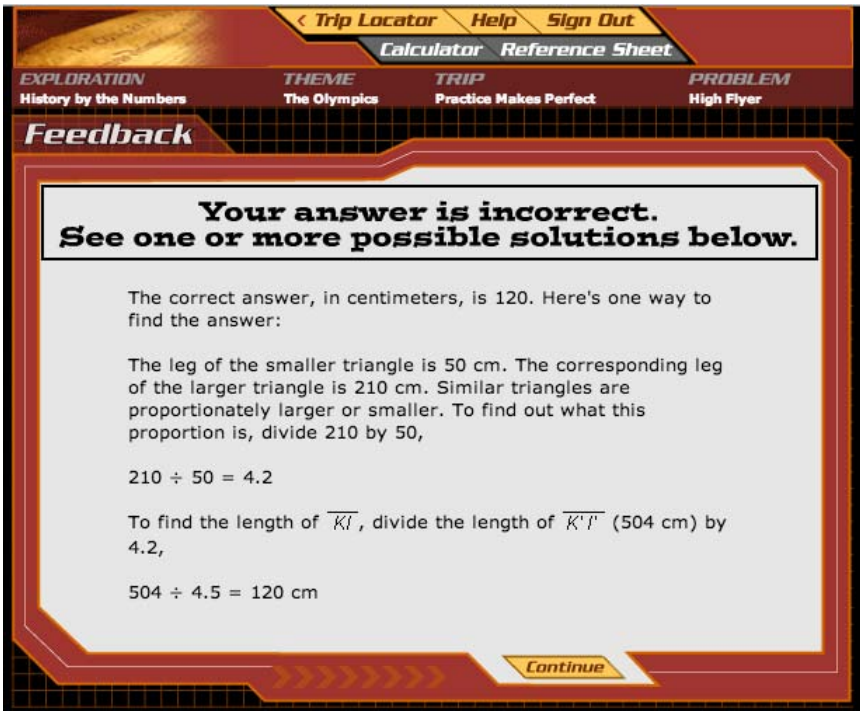


**Your answer is incorrect.
See one or more possible solutions below.**

Read the question again and think about the properties of similar triangles. Remember that similar triangles increase or decrease in proportion to each other.

Click for definitions:
similar figures

Figure 2.4 First Incorrect Answer Hint Screen



Your answer is incorrect.
See one or more possible solutions below.

The correct answer, in centimeters, is 120. Here's one way to find the answer:

The leg of the smaller triangle is 50 cm. The corresponding leg of the larger triangle is 210 cm. Similar triangles are proportionately larger or smaller. To find out what this proportion is, divide 210 by 50,

$210 \div 50 = 4.2$

To find the length of $\overline{KI}$, divide the length of $\overline{K'I'}$ (504 cm) by 4.2,

$504 \div 4.5 = 120$ cm

Figure 2.5 Second Incorrect: Correct Answer Explanation (CAE)

The student has the choice to Continue and, upon clicking that button, a new problem is presented while the current problem, in this case the Ski Jumper, is placed on the student's Challenge List and is available for the student to attempt to solve during the next day. The FCAT Explorer program adds the Ski Jumper problem back to the student's problem list after the date change occurs at midnight of that day.

If the student correctly answers the next problem, the screen with the reward graphic Figure 2.6 appears. This reward graphic is not static, but rather provides a colorful display that moves across the screen as shown in the detail Figure 2.7.

Did you use the solution below to solve this problem?

The correct answer is B, 13.6 miles per hour. Let's take a look at how we got this answer:

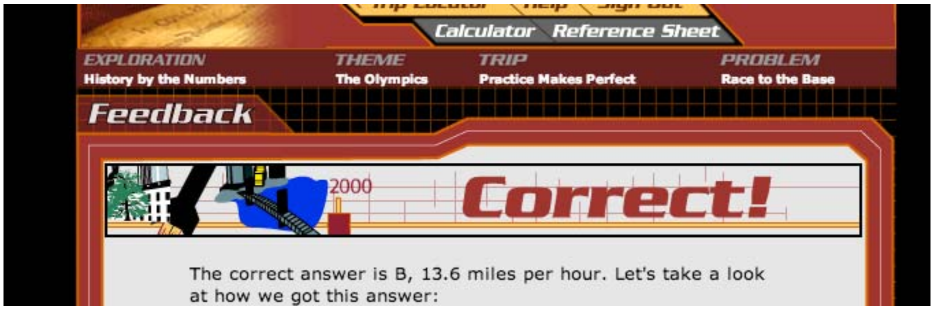
We know that Raul's average speed is 20 feet per second. First, use the conversion for seconds to hours to find his speed in feet per hour,

1 hour = 3600 seconds 20 feet per second × 3600 seconds/hour = 72000 feet per hour

Now, use the conversion 1 mile = 5280 feet to convert feet per hour to miles per hour,

1 mile = 5280 feet
72000 feet per hour ÷ 5280 feet/mile = 13.6 miles per hour

Figure 2.6 CAE Screen with Reward Graphic



The correct answer is B, 13.6 miles per hour. Let's take a look at how we got this answer:

Figure 2.7 Detail of Reward Graphic Motion

2.4.5 *Effectiveness of Technology-Assisted Instruction*

Researchers have examined the effectiveness of FCAT Explorer in terms of student achievement. In 2002, a sample of 961 grade 5 students in Leon County, Florida participated in a project (Naime-Diefenbach & Sullivan, 2003) to determine the relationship between students' FCAT Explorer performance scores and their scores on the actual FCAT mathematics test. The study linked the accuracy of students’ first and second responses with the number of FCAT practice problems attempted and the students’ score. Also the number of correct-answer explanation screens read by the students was linked to FCAT scores. However, the relationship between FCAT Explorer performance and actual FCAT scores remained unsupported. In another study that analyzed both reading and mathematics scores for the 2001 and 2002 FCAT tests (Martindale et al., 2005), findings regarding the effectiveness of using FCAT Explorer were less than convincing.

While research suggests that online learning can contribute positively to learning outcomes (Goldenberg & Cuoco, 1996; Sanders, 2001), accommodate different learning styles (Hawkins, 1993; Schank, 1993), lead to different perceptions of the learning environment based on gender (Khoo & Fraser, 2008), increase meaningful dialogue amongst students (McDonald & Hannafin, 2003), and generate important data about student achievement (Naime-Diefenbach & Sullivan, 2001), the question still remains about whether or not computer-supported learning can contribute positively to improvements in achievement scores.

Whereas computers and the Internet have been a potential source of educational improvement, the use of technology in education has almost a full century of history. For example, the motion picture as an educational resource, according to Thomas Edison in 1913, would render textbooks obsolete and change schools within 10 years (Saettler, 2004). In contrast to this claim, textbooks are still being used frequently in classrooms (Oser, 2013).

A more prevalent phenomenon than unfulfilled claims for the use of technology in education is the presence of the ‘no significant difference phenomenon’ (Russell, 1999). A variety of technology has been used in the classroom and evaluated in numerous studies that have revealed little impact. Table 2.3 lists 13 studies involving educational technology that were conducted over several decades, together with the type of technology, the focus of the comparison, and a summary of observed results.

Despite evidence to the contrary, research results are either overlooked or ignored as the newest, most expensive technology and software are brought to bear on education in the stubborn hope that they will deliver the promised positive impact on learning and test scores. An example currently unfolding in Miami is the impending implementation of Miami-Dade County Public Schools iPrep Mathematics laboratories throughout the district. This involves the core curriculum tool Carnegie's Cognitive Tutor/*Mathia*, a program that has had little or a negative impact on student learning (U.S. Department of Education What Works Clearinghouse, 2010). A meta-analysis of 24 studies that were undertaken by the What Works Clearinghouse (WWC) identified only two studies that fully met the high school review protocols, as well as another two studies that met the protocol with reservations, in terms of what was considered to be extensive evidence for an evaluation. This meta-analysis often revealed 'no discernible effects', with an improvement index ranging from -7 to +2 percentile points and with an average of -4 percentile points. These results seem to follow the pattern described in Table 2.3. Another meta-analysis of 45 studies of 50 effect sizes suggested that, while online learning was modestly more effective, 9 of the 11 studies favored the online approach over the traditional entirely face-to-face method or a blended learning approach. Implicit in these finding is the importance of an effective classroom environment as a contributing factor (U.S. Department of Education, 2010).

A review of the literature regarding the impact or lack of impact of using technology in education over the last century is far beyond the scope of this study. However, it is noteworthy that my study made an attempt to use psychosocial evaluation tools to provide insight into the impact of a particular technology program. Learning environment research provides an abundance of robust instruments with which to measure students' perceptions of their learning environment, including the TROFLEI, which I used to evaluate the effectiveness of using FCAT Explorer in terms of both its impact on the classroom learning environment.

Table 2.3 No Significant Differences in Studies of the Effectiveness of Technology in Education

Study	Technology	Focus of Study	Results
Loder (1937)	Loudspeakers	Face-to-face instruction v. distance education	No significant difference
Rulon (1943)	Phonographic recordings	Face-to-face instruction v. distance education	No significant difference
Woelfel & Tyler (1945)	Instructional radio	Face-to-face instruction v. distance education	No significant difference
Van der Meer (1950)	Sound films, sound films plus study guides, standard lecture	3 separate instructional methods	No significant difference between three groups
Kanner (1950)	Television	Face-to-face instruction v. distance education	No significant difference
Seibert & Honig (1960)	Televised laboratory instruction	Face-to-face instruction v. distance education	No significant difference
Beard, Lorton, Searle et al. (1973)	Computer-assisted instruction (CAI)	CAI with traditional methods	No significant difference
Partin & Atkins (1984)	Electronic black board	Technology with traditional methods	No significant difference
Cennamo (1990)	Interactive video	Technology with traditional methods	No significant difference
Goldberg (1997)	Internet	Integrated internet resources in classroom	No significant difference
Mock (2000)	Internet	Online classes	No significant difference
Moss (2007)	Interactive white board	Technology with traditional methods	No significant difference
Weisberg (2011)	E-Reader/tablet device	Technology with traditional methods	No significant difference

2.5 Chapter Summary

Chapter 2 reviewed literature that provides a framework for my study of the effectiveness of the FCAT Explorer, an online mathematics tutorial program for the middle grades, in terms of the students' perceptions of their learning environments and their attitudes towards mathematics.

This chapter reviewed literature in three broad categories. The first area was the field of learning environment research, which began with the seminal work of Lewin in 1938 for examining the psychosocial elements that contribute to the dynamics of work environments. From there, the beginnings of contemporary educational learning environment research started with an evaluation of Harvard Project Physics by Walberg in 1968 and Moos's work in a variety of human environments, that led to the creation of instruments specifically to measure student perceptions of their classroom environment. This chapter also provided a review of numerous instruments for assessing students' perceptions of classroom learning environments, including the What Is Happening In this Class? (WIHIC) and the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI). A review of past research applications using these instruments covered several areas: improving classroom environments; cross-national studies; evaluation of educational innovations; and associations between the learning environment and student outcomes.

The second area addressed in this chapter was the field of attitude assessment, including a review of literature on the Test of Mathematics Related Attitudes (TOMRA), which is derived from the widely-used Test of Science Related Attitudes (TORSA).

The third area reviewed was online resource tools. A review was provided of the growing use of computers to support classroom activities in general, as well as the specific program FCAT Explorer. A brief review of research on technology implementation over the last several decades often revealed a nonsignificant impact.

Chapter 3

RESEARCH METHODOLOGY

3.1 Introduction

With the increasing emphasis on measuring student achievement by means of high-stakes tests, coupled with increasing expenditure on technology such as computers, tablets, and online resources, there is a similarly increasing need to evaluate the benefit returned on the investments. For this research, I evaluated the online mathematics program FCAT Explorer in terms of the classroom environment and students' attitudes, and also investigated associations between the classroom environment and the attitudes of students.

Chapter 1 provided information about the background and theoretical framework of the study. Chapter 2 reviewed relevant literature, especially previous learning environment studies that focused on science or mathematics classrooms. The significance of this study is that it is the first documented research using learning environment instruments to investigate students' perceptions of their mathematics classroom environment in the context of using the FCAT Explorer program as a major element of the classroom curriculum. It also was the first time that a large sample of middle-grade students in the USA was administered the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI), an instrument that is based largely on the robust, contemporary environment instrument What Is Happening In this Class? (WIHIC). Furthermore, a final unique characteristic of my study is that this was the first time that the FCAT Explorer was evaluated in terms of students' attitudes toward mathematics using attitude scales from the Test of Mathematics-Related Attitudes (TOMRA).

This study also followed the tradition in past learning environments research of exploring connections between students' perceptions of their classroom environment and student outcomes as measured by their attitudes towards mathematics. This study answered the following questions:

1. Are the TROFLEI and TOMRA valid when used in technology-supported middle-school mathematics classes?

2. Is the FCAT Explorer effective as a curriculum supplement for traditional mathematics instruction in terms of:
    i. students' perceptions of their classroom learning environment
    ii. students' attitudes to mathematics?

3. Are there associations between students' perceptions of technology-supported classroom environments and their attitudes to mathematics?

This chapter describes the methods for answering the research questions. Section 3.2 addresses the data sources and sample for the study, Section 3.3 describes the quantitative research methods, and Section 3.4 is devoted to the questionnaires used. Section 3.5 identifies how questionnaire data were analysed to answer my research questions. My qualitative data collection and analysis form the basis of Section 3.6. Section 3.7 provides a discussion of some limitations of my study.

3.2 Data Sources and Sample

The study was conducted in a public school in Florida. The Miami public school system, known as Miami-Dade County Public Schools (MDCPS), has a student enrolment of 348,787 (FLDOE 2013~2014). The ethnic composition of the district comprises a majority of Hispanic students (66.7%), followed by 23.5% Black Non-Hispanic, 8% White Non-Hispanic, and 1.8% Other (American-Indian, Asian, and Multiracial students). Spanish is the primary language for 188,124 students and Haitian-Creole is the primary language for 15,771 students. MDCPS is the fourth largest school district in the United States.

Dade County has 173 elementary schools, 43 Kindergarten through grade 8 schools (K–8 Centers), 60 middle schools, and 43 senior-high schools. As discussed earlier in Section 1.2, MDCPS has seen a growth in the number of Charter Schools. Because Charter schools are part of the public education system, they still receive state funding for student attendance. In contrast to public schools which receive funding both for teaching students and for the physical school site, Charter schools only receive funds on a per-student basis from the state. This means that the school buildings, parking lots and, in some cases, the roads leading to the school must be paid for by the particular Charter School. Charter Schools also have considerably more curriculum freedom. Currently, Charter Schools in Dade County include 26 elementary schools, 32 K–8 Centers, 23 middle schools, and 32 senior-high schools (MDCPS Statistical Highlights 2012~13).

My study was conducted at Ammons Middle School, which was established in 1998 in southern Dade County for grades 6 to 8 students. The enrolment at this school is 1165 students and its ethnic composition is: Hispanic 65.1%, Black Non-Hispanic 12.8%, White Non-Hispanic 17.9%, Other 4.3%. Seven years ago, this school became the first in MDCPS to be authorized as an International Baccalaureate Middle Years Programme, which is offered school-wide at the three grade levels.

The school is made up entirely of portable classrooms that were used as temporary housing during the reconstruction effort after Hurricane Andrew in 1992. Classrooms have many windows which admit an abundance of natural light into the classroom. Most of the classrooms are equipped with, in addition to computers, LCD projectors, telephones, and even toilet facilities.

All students were invited and encouraged to participate in the study after a letter describing the nature of the study was sent home with every student to obtain parental approval for participation. There were only three students whose parents withheld permission for them to participate. A copy of the Parent Approval Letter is included in Appendix B.

3.3 Online Mathematics Program: FCAT Explorer

Because evaluating one specific piece of technology, namely, the FCAT Explorer, was the focus of my study, a brief explanation of this online mathematics program is given here in the context of its role in this study. A more thorough explication of FCAT Explorer was provided as part of the review of the literature in the second chapter of this thesis (Section 2.4).

FCAT Explorer is an online program which offers students a group of practice problems in both reading and mathematics that are specific to each grade level (Florida State Department of Education, 2005). The mathematics program has benchmark-specific problems for the 5th, 8th and 10th grades and Correct Answer Explanation, that furnishes students with a cohesive explanation of the problem and its concepts when the student answers the question correctly. When a student answers a question incorrectly, the program provides a hint about how to solve it and immediately gives the student a second chance to apply the hint. If the student is unsuccessful at the second attempt, the student goes on to the next problem and the missed problem appears on a challenge list. Before completing a section, the student must answer all questions in the challenge list. Because the program is provided as an online resource, the type, age, and operating system of the computer used to access it is relatively open. FCAT Explorer can accommodate a variety of Windows operating systems, including Windows 98, ME, Windows 2000, Vista and Windows 7/8, as well as Mac OS 9 and Mac OS X. Browser compatibility includes Internet Explorer, Netscape, Mozilla, Opera, Compuserve, AOL, NetZero, EarthLink, and BellSouth. Flash compatibility is required, which poses a compatibility issue with iOS devices that are not Flash compatible.

Student performance data are provided via the teacher login for FCAT Explorer. Teachers can obtain feedback about performance results for their students, and these performance data can be displayed for individual students or for a whole class, thus providing further options for the teacher.

3.4 Instruments for Quantitative Data Collection

The design chosen for this study involved the administration of a learning environment instrument (TROFLEI) and an attitude questionnaire (TOMRA) as pretests and, after a specific period of time, as posttests. The specific period of time was the 10-week period between the beginning of a marking period, mid-January, and the beginning of April when the FCAT was administered at the middle school. This design differs from some other learning environment studies that have relied on a single questionnaire administration to assess students' perceptions of the actual classroom environment and their preferred classroom environment. The TROFLEI and TOMRA were administered to a sample of 914 students in 49 grades 6–8 mathematics classes who were present for both the pretest and posttest. Given the size of the instrument (104 items), an entire class period of 85 minutes was devoted to completing the questionnaires at the beginning of March. After the pretest was completed, students then embarked on a 10-week program involving the nine sections of the FCAT Explorer.

All seven mathematics teachers at the school met with me to discuss the project, become somewhat familiar with the TROFLEI and TOMRA, and to be trained in the administration of the questionnaire. The instructions were for the instrument to be taken and completed by the students in each mathematics class during one class period of 85 minutes duration. Then, the questionnaires were collected by the teachers and returned to me. Provisions were made for absent students to complete the questionnaire upon their return to class. Because the school operates on a block schedule (meaning that each teacher meets with all of his/her students on a two-day rotation), a week was allotted to the pretest administration so as to accommodate the teachers' lesson plans and activities.

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

The Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) was discussed at length in Section 2.2.2.10, but a summary of salient points is included here. The TROFLEI draws upon all seven scales of Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation and Equity from the WIHIC (What Is Happening In this Class?). In addition to these WIHIC scales, the TROFLEI includes the three new scales of Differentiation, Computer Usage, and Young Adult Ethos to provide relevance to classrooms that involve ICT and outcomes-focused learning. The TROFLEI originally contained 80 items including 8 items for each of the 10 scales but, after field testing and validation, modifications were made while retaining the original 10 scales (Aldridge & Fraser, 2008). To reduce student confusion, the TROFLEI was arranged with all items related to a particular scale in a single block rather than arranged randomly cyclically, or in some other order.

The literature supporting the successful use of the WIHIC is voluminous and the literature supporting the TROFLEI, while not as large, is growing (see Chapter 2). For example, a study drawing upon data from 2317 Australian students in 166 classrooms (Aldridge & Fraser, 2008) investigated the factorial validity and internal consistency reliability of the TROFLEI. As well, the TROFLEI has been translated, validated and used in Turkey with a sample of 980 grade 9–12 students, in addition to as English-language version being used with 130 grade 9–12 students in the USA (Welch, Cakir, Peterson & Ray, 2012). Koul, Fisher and Shaw (2011) used the TROFLEI with a sample of 1027 high-school students from 30 classes in New Zealand. As well as cross-validating the TROFLEI in both its actual and preferred forms, the New Zealand study revealed sex and grade-level differences in perceptions, as well as attitude−environment associations.

3.4.2 Test of Mathematics Related Attitudes (TOMRA)

In addition to the TROFLEI scales for assessing learning environment, my study also incorporated three scales from the Test of Mathematics-Related Attitudes (TOMRA), which is based on Fraser's (1981a) Test of Science-Related Attitudes (TOSRA). In its original form, the TOSRA measured seven science-related attitudes that are built upon Klopfer's (1971) original six categories of attitudes. The widely-used TOSRA was selected as the basis for my study because it overcomes most of the problems of attitude assessment identified by Kind, Jones and Barmby (2007) and Munby (1997).

TOSRA was designed originally to assess students' attitudes specifically to the subject of science, but various researchers have adapted it for other subjects. For example, several researchers in the USA changed the word 'science' to 'mathematics' to form the Test of Mathematics Related Attitudes (TOMRA). Examples include Ogbuehi and Fraser's (1997) research in California and Spinner and Fraser's (2005) study in Florida. TOSRA also has been adapted and successfully used in geography (Walker, 2006) and English classes (Liu & Fraser, 2013).

For this study, a modified version of the TOMRA was used with fewer than the full complement of scales. The specific TOSRA scales that were chosen as being the most salient for my study and then adapted were Enjoyment of Mathematics Lessons, Normality of Mathematicians and Attitude to Mathematical Inquiry. Each of these three scales was comprised of eight items which, when added to the 10 eight-item scales of the TROFLEI, brought the total number of items in my study to 104.

3.5 Analysis Methods for Questionnaire Data

Quantitative data collection involved pretest and posttest administrations of questionnaires separated by a 10-week period during which the FCAT Explorer was used by students in grades 6–8. Once collected, the quantitative data were analyzed in a number of ways described in greater detail below. Section 3.5.1 discusses the data analyses for validating the TROFLEI and the modified TOMRA. Section 3.5.2 presents the data-analysis methods for evaluating the effectiveness of the FCAT Explorer in terms of students' perceptions of their classroom environment and attitudes towards mathematics. Section 3.5.3 describes methods of data analysis for investigating associations between classroom environment and student attitudes. In contrast, my methods of qualitative data collection and analysis are the focus later in Section 3.6.

3.5.1 Validity of Instruments

My first research question was: Are the TROFLEI and TOMRA valid when used in technology-supported middle-school mathematics classes? To answer this question, I conducted various analyses of the data collected from the 914 students who provided useable data for both the pretest and posttest administrations of the questionnaires.

For the 10-scale 80-item TROFLEI, responses from the sample of 914 students were analysed using principal axis factoring with varimax rotation and Kaiser normalisation. A factor analysis was conducted separately for pretest responses and posttest responses. Criteria for the retention of any item (namely, that it must have a factor loading of at least 0.40 on its own scale and less than 0.40 on each of the other nine TROFLEI scales) were used to identify and subsequently remove any items. The percentage of variance and eigenvalue also were calculated for each TROFLEI scale. The results of the factor analysis are presented later in Section 4.2.1.

For the TOMRA's 24 items in the scales of Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry and Normality of Mathematicians, a similar principal axis factor analysis with varimax rotation and Kaiser normalization was conducted. Again factor analysis of the pretest and posttest responses was conducted separately. The same criteria used for retention of TROFLEI items (a factor loading of at least 0.40 on its own scale and less than 0.40 on the other scales) were used for the TOMRA. The results of factor analysis for the TOMRA are presented later in Section 4.2.2.

The internal consistency of a scale is a measure of how well items within that scale are intercorrelated and therefore measure a common construct. In my study, the internal consistency of each TROFLEI and TOMRA scale was assessed using Cronbach's alpha coefficient. Alpha coefficients were calculated separately for pretest and posttest data and separately for two different units of statistical analysis, namely, the individual student and the class mean. Reliability results are reported later in Tables 4.3 and 4.4.

Scales within the same questionnaire should not correlate highly with one another because they are supposed to be measuring different constructs. In this study, the mean correlation of a scale with the other scales in the same questionnaire was used as a convenient index of discriminant validity (again for the same two units of analysis). Tables 4.3 and 4.4 later report results for discriminant validity.

The ability of scales to differentiate between the perceptions of students in different classes is an important and valuable characteristic for the actual form of a classroom environment instrument (but is not relevant for the attitude questionnaire). Whereas students within the same classroom should have similar perceptions of that classroom, students' perceptions should differ from classroom to classroom. ANOVA was used to check the ability of each actual TROFLEI scale to differentiate between the perceptions of students in different classrooms. ANOVA was conducted for each actual TROFLEI scale for the posttest with class membership used as the independent variable. The eta^2 statistic, which is the ratio of the ‘between’ to ‘total’ sum of the squares, was used to represent the proportion of variance explained by class membership for each TROFLEI scale. These results are presented later in Table 4.3.

3.5.2 Evaluation of FCAT Explorer

Research question #2 was: Is the FCAT Explorer effective as a curriculum supplement for traditional mathematics instruction in terms of:

a. students’ perceptions of their classroom learning environment
b. students’ attitudes to mathematics?

For this research question, differences between pretest and posttest scores for the 10 TROFLEI and three TOMRA scales were investigated using effect sizes and MANOVA with repeated measures. The average item mean and average item standard deviation were calculated for each scale. If the multivariate test using Wilks’ lamda criterion revealed statistically significant pre–post differences for the whole set of independent variables, then the results for the individual ANOVA with repeated measures was interpreted for each of the 13 scales.

The effect size for each scale was used to portray the magnitude of pre–post differences. The effect size, which is the difference between pretest and posttest means expressed in standard deviation units, is calculated by dividing the difference between means by the pooled standard deviation. The use of effect sizes helps in identifying the educational importance of statistically significant results (Thompson, 1998).

3.5.3 Attitude–Environment Associations

To answer my third research question (Are there associations between students’ perceptions of technology-supported classroom environments and their attitudes towards mathematics?), simple correlation and multiple regression analyses were used. The bivariate association between each attitude scale and each learning environment scale was provided by the simple correlations. The multiple correlation was used to portray the multivariate association between an attitude scale and the set of all TROFLEI scales. The regression weights were used to determine the associations between each TROFLEI scale and a TOMRA scale while scores of the other nine TROFLEI scales were mutually controlled. The analyses were conducted separately for pretest and posttest data and separately for two units of analysis (the student and the class mean). The results of these analyses are presented in Section 4.4.

3.6 Methods of Qualitative Data Collection and Analysis

Although my study relied primarily on quantitative data involving learning environment and attitude questionnaires, it also incorporated a minor but still important qualitative component involving student interviews. The value of combining quantitative and qualitative data in mixed-methods research has been widely endorsed in the literature (Cresswell & Plano Clark, 2007; Teddie & Tashakkori, 2009). The triangulation of quantitative and qualitative data has the potential to minimize the weaknesses of each method and to capitalize on their strengths (Green & Caracelli, 1997).

Specifically for learning environment research, Tobin and Fraser (1998) advocated combining qualitative methods, illustrated the benefits with some case studies, and claimed that "we cannot envision why learning environment researchers would opt for either qualitative or quantitative data and we advocate the use of both in an effort to obtain credible and authentic outcomes" (p. 639). In their study of classroom environments in Taiwan and Australia, Aldridge, Fraser and Huang (1999) illustrate the benefits of integrating the use of a quantitative learning environment questionnaire with qualitative narrative stories and interpretative commentaries.

Discussion of my qualitative methods below is organized into three subsections that focus on the interview procedures (Section 3.6.1), reporting interviews using a narrative (Section 3.6.2), and analysing written interview comments using themes (Section 3.6.3).

3.6.1 Interviews

To add to the overall richness of my research, case-sampling open-ended interviews were undertaken to clarify and amplify the findings from the quantitative data collection. The goal was to use qualitative student responses to provide either confirmation or contradiction for the quantitative questionnaire results through questioning students about their perceptions of and attitudes towards their mathematics classrooms in general and the FCAT Explorer in particular.

A group of 24 student volunteers were interviewed using 7−12-minute interviews in a face-to-face setting. Of the 24 students, 9 were male and 15 female, and there were 3 grade 7 students and 21 grade 8 students. Each interview consisted of 10 questions and I took notes based on students' responses (with their permission). After giving verbal responses, the students were then given a copy of the interview questionnaire so that they could write their responses to those questions. The written responses were used in the data analysis, but not the verbal responses. The reasons for using this method were to allow students to discuss their thoughts verbally, to have ample opportunity for reflection, and to crystallize these responses by writing them down on paper. Therefore the verbatim written responses to the interview questions became the unit of analysis.

In conducting effective interviews, guidance was obtained from sources such as Patton (2002), Erickson (2012), Denzin and Lincoln (2008) and Kvale (1996). In terms of maximizing the rigour, reliability and dependability of the interviews, insights were gleaned from Cresswell and Plano Clark (2007) and Lincoln and Guba (1985).

Open-ended questions have been used in past classroom environment studies (Khoo & Fraser, 2008; Patton, 2002) to obtain a more in-depth view of student perceptions. To enhance the integration of quantitative and qualitative data, careful thought went into the design of the questions. The first four questions of the interview were introductory in nature, including the student's name, grade, current mathematics class and the class taken in the previous year. Students were assured that personal information of any kind would not be needed, asked for or published.

The remaining six questions formed the core of the interviews. With 10 TROFLEI environment scales and three TOMRA attitude scales included in my quantitative data collection, having an interview question for every scale would have been excessively time-consuming and therefore potentially counter-productive. Therefore I decided to have an open-ended interview question for each of five TROFLEI scales and one TOMRA attitude scale. The TROFLEI scales addressed in the interview questions were Teacher Support, Investigation and Orientation to Task, Student Cohesiveness and Cooperation, Computer Usage, and Young Adult Ethos. For the TOMRA attitude scales, an interview question was designed to elicit students' responses regarding the ways in which the use of the FCAT Explorer had changed their attitudes about mathematics. The interview questions are provided later in Section 4.5 and in Appendix C.

3.6.2 Narrative

Analysis of qualitative data can be undertaken in a variety of ways. For this study, the first format was a narrative that attempted to create a story that included a composite of student responses in a real-life setting (Aldridge, Fraser, & Huang, 1999; Clandinin & Connelly, 1994; Silverman, 2000). Because I was the researcher and also a classroom teacher, I used student responses to portray to the greatest possible degree the typical classroom environment in the school where the study took place, as well as to provide a context for students' written responses.

This narrative, presented later in Section 4.5.2, describes imaginary out-of-town visitors who enter several classrooms and chat with students.

3.6.3 Themes

The second approach that I used with the qualitative data involved analyzing written interview responses in terms of general ideas or topics, and then linking these ideas and topics to higher-order, emerging themes in a columnar format (Taylor & Fraser, 2013). For this process, each student's response to the six core questions was categorized using a coding scheme (Richards & Morse, 2007). With 24 student interviews, this provided a sample space of 144 separate responses, using the word-for-word written responses as the unit of analysis. Using a process similar to factor analysis, these responses were then grouped into an intermediate-level summary that categorized them as being representative of an idea or topic.

Some examples of these ideas/topics, identified later in Section 4.5.3, include Engagement, Mathematical Process, Workflow, Boredom, and Satisfaction. From these ideas/topics, a link to one of the six TROFLEI and TOMRA scales included was attempted, and an analysis of students' qualitative responses was undertaken to confirm or contradict the findings that had emerged from my analysis of quantitative questionnaire data for each of the six constructs included in the interviews.

My analysis of interview responses involved an inductive method, advocated by several researchers (Patton, 1992; Silverman, 2000; Taylor & Fraser, 2012), in which themes that emerge from interviews are combined into higher-order groupings of the main conceptual ideas of those themes. This forms an analysis structure with three levels. The first level is the student response or the initial unit of analysis. The second level begins to combine responses into a higher-order grouping. From this second level, I identified themes that took on the expected form of the constructs selected from the TROFLEI and TOMRA. The results of this thematic analysis can be found later in Chapter 4 (Section 4.5.3 and Figure 4.1).

3.7 Some Limitations of Study

As with all studies involving human beings, my study had limitations that potentially could have affected the findings of my investigation (Brutus et al., 2013). One methodological limitation was the size and composition of the sample. Limitations in sample size can reduce the statistical power of analyses, whereas limitations in sample representativeness can reduce the generalizability of findings. With the support of the school principal, the entire student body of 1154 students were available for the study, but the final number of students with complete responses to questionnaires for the quantitative data analysis dropped to 914. The district in which the study took place serves almost 350,000 students, but my study included less than 0.3% of the district's student population. The sample in this study, however, was large in comparison with other learning environment studies and, indeed, was the largest possible size available at the school because no students were left out of the sample.

The school involved in this study is a magnet school at which the students who attend have to pass minimum acceptance criteria for academic performance and behavior. Because these criteria that are not the norm for non-magnet schools, a further limitation of my research is the possible low generalizability of results to non-magnet schools.

The nature of the enrolment process at this particular school involved a concerted effort to match the ethnic make-up of the school with that of the district. Therefore, a potential limitation concerning ethnic make-up being atypical did not arise (and therefore did not threaten generalizability).

Because of a lack of past research involving the FCAT Explorer, my combination of research methods had not previously been attempted. Therefore, I consulted reports of previous studies that had used learning environment instruments to investigate other educational programs (e.g. Spinner & Fraser, 2005) and studies of the FCAT Explorer that had employed other evaluative criteria (e.g. Naime-Diefenbach & Sullivan, 2003) to help me to shape appropriate methods for my study.

Because responding to questionnaires containing 104 items was potentially taxing for my sample of middle-school students aged 11–14 years, there was potential for students not to respond seriously to questionnaire items. To address this concern, I personally visited each of the 45 classes involved in this study to give a brief 4–5-minute ‘pep talk’ to the students so that I could emphasize the importance of their taking the questionnaire seriously. I also used that opportunity to point out that having some questionnaire items that are similar to each other is common with this type of instrument because it improves scale reliability.

A fuller discussion of my study’s limitations can be found in Chapter 5 (Section 5.4).

3.8 Summary

This chapter provided a description of the methods used in my research. Starting with the data sources, a brief discussion was provided of the region, district and school involved in order to better portray the context in which the study took place. This included information about the data sources, the method of selecting the sample, the implementation of the research design, and data collection (Section 3.2). The sample size for my project was 914 middle-grade mathematics students. Because the main focus of my study was to evaluate the effectiveness of the online resource, FCAT Explorer, in terms of the students' perceptions of their learning environments and their attitudes towards mathematics, FCAT Explorer was described in Section 3.3 and the instruments chosen for the study were discussed in Section 3.4.

To answer my first research question, the quantitative questionnaire data collected with the TROFLEI and modified TOMRA were statistically analyzed in terms of factor structure, internal consistency reliability and the ability to differentiate between classrooms. To answer my second research question concerning the effectiveness of using FCAT Explorer, pretest–posttest changes in learning environment and attitude scales were analysed using MANOVA and effect sizes. My third research question concerning associations between learning environment and attitude scores was answered using simple correlation and multiple regression analyses.

Quantitative data were augmented by qualitative information based on 24 personal interviews with students who volunteered to share their thoughts with me. These interviews were categorized into six core questions based on learning environment and attitude constructs encompassed by the TROFLEI and TOMRA, thereby providing 144 separate and distinct responses that were recorded in writing word-for-word. Interview data were reported by means of, firstly, a narrative and, secondly, an analysis of themes.

Chapter 4 provides a detailed reporting of the analyses and results for each of the research questions in my study.

Chapter 4

DATA ANALYSES AND RESULTS

4.1 Introduction

The main objective of this research was to evaluate the use of online resource material for supporting a traditional mathematics curriculum by using learning environment and attitude instruments. Therefore my primary research question was based upon evaluating the effectiveness of the FCAT Explorer among a sample of middle-school students in terms of the students' perceptions of learning environments and their attitudes towards mathematics. A second research focus was the validation of the chosen learning environment questionnaire, the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI), with an ethnically-diverse sample of middle-grade mathematics students in Florida. Finally, associations between classroom environment and student attitudes were investigated as well. The research questions for this study were:

> Are the TROFLEI and TOMRA valid when used in technology-supported middle-school mathematics classes?
>
> Is the FCAT Explorer effective as a curriculum supplement for traditional mathematics instruction in terms of:
>
> - students' perceptions of their classroom learning environment
> - students' attitudes to mathematics?
>
> Are there associations between students' perceptions of technology-supported classroom environments and their attitudes to mathematics?

The instruments, TROFLEI and TOMRA, were reviewed in detail in Chapter 2. The TROFLEI draws heavily on the much-validated WIHIC, while the TOMRA is a modification of the also well-validated TOSRA. The TROFLEI assesses students' perception with the 10 scales of Student Cohesiveness, Teacher Support, Involvement, Young Adult Ethos, Investigation, Task Orientation, Cooperation, Equity, Differentiation, and Computer Usage. The 8 items for each scale are arranged together as a group so as to minimize student confusion. The total number of items is 80 for the TROFLEI. The TOMRA was used to assess student attitudes towards mathematics and mathematicians using the three 8-item scales of Enjoyment of Mathematics, Attitude to Mathematical Enquiry, and Normality of Mathematicians. Therefore, the questionnaire used for this study consisted of the 10 TROFLEI scales, with the 3 TOMRA scales immediately following, to form a 104-item questionnaire.

As noted in Chapter 3, the sample for analyses of quantitative questionnaire data reported in the chapter consisted of 914 students in 49 grade 6–8 mathematics classes in Florida. The qualitative component of my study involved interviews with 24 students.

4.2 Validity and Reliability of the Questionnaires

For Research Question 1, involving validity of the instruments, principal axis factor analysis with varimax rotation and Kaiser normalization was conducted to investigate the structure and validity of the scales separately for the 10-scale TROFLEI and three-scale TOMRA. The criteria for the retention of any item were that it must have a factor loading of at least 0.40 with its own scale and less than 0.40 with all other scales. Items whose factor loadings did not meet these criteria were removed.

As well, Cronbach's alpha coefficient was calculated for each scale as an index of its internal consistency reliability. Furthermore, an analysis of variance (ANOVA) was used to investigate each TROFLEI scale's capability at differentiating between students in different classes.

4.2.1 Factor Structure of TROFLEI

In order to check the structure of the 10-scale 80-item TROFLEI, responses from the sample of 914 students were analyzed separately for pretest responses and posttest responses using principal axis factoring with varimax rotation and Kaiser normalization. Applying the criteria for the retention (that any item must have a factor loading of at least 0.40 on its own scale and less than 0.40 on each of the other nine TROFLEI scales) led to the identification and subsequent removal of 14 items, leaving the 66 items listed in Table 4.1. The items omitted were: Items 3, 5, 6, and 8 from Student Cohesiveness; Item 16 from Teacher Support; Items 19, 21, 22, 23 and 24 from Involvement; Items 57, 58 and 61 from Differentiation; and Item 72 from Computer Usage.

Table 4.1 shows that, for the refined version of the TROFLEI containing 66 items in the original 10 scales, every item's factor loading was greater than 0.40 on its own scale and less than 0.40 on each of the other nine TROFLEI scales. The bottom of Table 4.1 indicates that the proportion of variance accounted for ranged from 2.18% to 7.36% for pretest responses to different TROFLEI scales, with the total variance accounted for by all 10 pretest scales being 50.94%. For the posttest, the percentage of variance accounted for by different scales ranged from 1.39% to 8.03%, with the total variance being 57.14%. As shown in Table 4.1, eigenvalues for different TROFLEI scales ranged from 1.44 to 5.30 for the pretest and from 2.10 to 4.86 for the posttest.

4.2.2 Factor Structure of the TOMRA

For the scales of Enjoyment of Mathematics Lessons, Attitude to Mathematical Inquiry, and Normality of Mathematicians drawn from the TOMRA and included in this study, I conducted a similar principal axis factoring with varimax rotation and Kaiser normalization with the sample of 914 students in 49 classes. Factor analysis of the pretest and posttest responses was conducted separately. The same criteria for retention used for the TROFLEI, namely, a factor loading of at least 0.40 on its own scale and less than 0.40 on the other two TOMRA scales, were used. Table 4.2 displays the factor analysis results. All 24 items satisfied the criteria for retention.

Table 4.1 Factor Analysis Results for the TROFLEI for Pretest and Posttest

Item No.	Factor Loadings																			
	Student Cohesiveness		Teacher Support		Involvement		Investigation		Task Orientation		Cooperation		Equity		Differen-tiation		Computer Usage		Young Adult Ethos	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	0.68	0.79																		
2	0.56	0.62																		
4	0.77	0.79																		
7	0.64	0.63																		
9			0.60	0.64																
10			0.66	0.67																
11			0.68	0.67																
12			0.50	0.47																
13			0.63	0.69																
14			0.68	0.74																
15			0.63	0.67																
17					0.57	0.61														
18					0.73	0.68														
20					0.53	0.50														
25							0.61	0.71												
26							0.56	0.59												
27							0.70	0.72												
28							0.56	0.62												
29							0.74	0.76												
30							0.80	0.78												
31							0.74	0.74												
32							0.69	0.70												
33									0.63	0.67										
34									0.61	0.62										
35									0.60	0.65										
36									0.59	0.64										
37									0.66	0.67										
38									0.62	0.59										
39									0.60	0.67										
40									0.57	0.64										
41											0.57	0.55								
42											0.55	0.58								

43											0.54	0.49								
44											0.52	0.47								
45											0.59	0.62								
46											0.65	0.68								
47											0.63	0.63								
48											0.59	0.59								
49													0.56	0.58						
50													0.62	0.61						
51													0.71	0.69						
52													0.74	0.74						
53													0.73	0.77						
54													0.72	0.76						
55													0.61	0.68						
56													0.69	0.67						
59															0.46	0.51				
60															0.58	0.65				
62															0.70	0.75				
63															0.57	0.63				
64															0.59	0.63				
65																	0.53	0.58		
66																	0.64	0.73		
67																	0.66	0.74		
68																	0.73	0.74		
69																	0.78	0.81		
70																	0.76	0.82		
71																	0.44	0.57		
73																			0.58	0.61
74																			0.54	0.55
75																			0.50	0.49
76																			0.56	0.60
77																			0.64	0.60
78																			0.62	0.60
79																			0.62	0.66
80																			0.48	0.54
% Variance	3.46	3.85	5.71	6.24	2.23	2.04	7.12	8.05	6.00	7.54	5.60	5.61	7.38	8.19	3.02	3.63	5.34	6.47	5.35	5.55
Eigenvalue	2.28	2.54	3.77	4.12	1.47	1.34	4.70	5.31	3.96	4.98	3.70	3.70	4.87	5.40	1.99	2.40	3.53	4.27	3.53	3.66

Items 3, 5, 6, 8, 16, 19, 21, 22, 23, 24, 57, 58, 61 and 72 were omitted.
The sample consisted of 914 students in 49 classes.
Factor loadings smaller than 0.40 have been omitted.
The total proportion of variance accounted for was 50.94% for the pretest and 57.14% for the posttest.

Table 4.2 Factor Analysis Results for TOMRA for Pretest and Posttest

Item	Factor Loadings					
	Enjoyment		Inquiry		Normality	
	Pre	Post	Pre	Post	Pre	Post
1	0.77	0.78				
2	0.71	0.73				
3	0.80	0.82				
4	0.85	0.86				
5	0.87	0.87				
6	0.85	0.84				
7	0.79	0.78				
8	0.73	0.76				
9			0.51	0.65		
10			0.58	0.68		
11			0.43	0.52		
12			0.65	0.73		
13			0.56	0.65		
14			0.66	0.72		
15			0.68	0.69		
16			0.68	0.71		
17					0.58	0.74
18					0.65	0.80
19					0.81	0.81
20					0.79	0.85
21					0.78	0.80
22					0.76	0.81
23					0.82	0.83
24					0.66	0.72
% Variance	22.67	23.42	13.98	17.84	21.57	24.06
Eigenvalue	5.44	5.62	3.35	4.28	5.18	5.77

Factor loadings smaller than 0.40 have been omitted.
The sample consisted of 914 students in 49 classes.
The total proportion of variance accounted for was 58.22% for the pretest and 65.32% for the posttest.

The percentages of variance for the scale Enjoyment were 22.67 and 23.42 for the prettest and posttest, with eigenvalues of 5.44 and 5.62. The percentages of variance for the scale Inquiry were 13.98 and 17.84, with eigenvalues of 3.35 and 4.28 for pretest and posttest data. The percentages of variance for the scale Normality were 21.57 and 24.06, with eigenvalue of 5.18 and 5.77.

The sections below focus on each scale's internal consistency reliability, discriminant validity, and ability to differentiate between classes. The results are reported in Section 4.2.3 (internal consistency), Section 4.2.4 (discriminant validity) and Section 4.2.5 (ability to differentiate between classrooms).

4.2.3 Internal Consistency Reliability of TROFLEI and TOMRA Scales

Internal consistency reliability is a measure of whether or not there is agreement of responses to similar items. To measure internal consistency, Cronbach's alpha coefficient was used. Table 4.3 displays the internal consistency reliability using the Cronbach alpha coefficient for each TROFLEI scale for two units of analysis, the individual and the class mean, and separately for pretest and posttest responses. Table 4.4 provides reliability results for the TOMRA.

The sample for reliability analysis consisted of a final total of 914 students in 49 classes. Table 4.3 shows that the alpha reliability coefficient for the 10 different TROFLEI scales for the individual unit of analysis ranged from 0.76 to 0.97 for the pretest and from 0.83 to 0.93 for the posttest. With the class mean unit of analysis, alpha coefficients ranged from 0.83 to 0.97 for the pretest and from 0.90 to 0.97 for the posttest. These values indicate a high degree of internal consistency reliability.

The TOMRA measures attitudes, as distinct from perceptions of classroom environment, and is therefore dealt with separately from the scales of the TROFLEI. Table 4.4 displays the internal consistency reliability using the Cronbach alpha coefficient for each TOMRA scale for two units of analysis and separately for pretest and posttest responses. The two units of analysis were again the individual and the class mean. The sample for reliability analysis again consisted of a final total of 914 students in 49 classes.

Table 4.3 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 Pretest and Posttest for TROFLEI

Scale	Unit of Analysis	No of Items	Alpha Reliability		Mean Correlation with other Scales		ANOVA Eta^2
			Pre	Post	Pre	Post	Actual
Student Cohesiveness	Individual	4	0.80	0.86	0.24	0.28	0.08**
	Class Mean		0.84	0.90	0.28	0.38	
Teacher Support	Individual	7	0.90	0.90	0.36	0.37	0.25 **
	Class Mean		0.97	0.97	0.57	0.57	
Involvement	Individual	3	0.81	0.84	0.33	0.35	0.15**
	Class Mean		0.91	0.94	0.44	0.44	
Investigation	Individual	8	0.91	0.92	0.34	0.37	0.11**
	Class Mean		0.96	0.96	0.50	0.43	
Task Orientation	Individual	8	0.86	0.90	0.28	0.35	0.12**
	Class Mean		0.90	0.94	0.41	0.50	
Cooperation	Individual	8	0.87	0.87	0.38	0.39	0.14**
	Class Mean		0.94	0.91	0.58	0.52	
Equity	Individual	8	0.91	0.93	0.32	0.38	0.16**
	Class Mean		0.97	0.97	0.61	0.61	
Differentiation	Individual	5	0.76	0.83	0.12	0.15	0.11**
	Class Mean		0.83	0.91	0.24	0.27	
Computer Usage	Individual	7	0.84	0.89	0.13	0.15	0.18**
	Class Mean		0.87	0.95	0.52	0.32	
Young Adult Ethos	Individual	8	0.86	0.90	0.27	0.37	0.17**
	Class Mean		0.94	0.96	0.59	0.59	

** p<0.01

The sample consisted of 914 students in 49 classes.

The eta^2 statistic (which is the ratio of 'between' to 'total' sums of squares) represents the proportion of variance explained by class membership.

Table 4.4 Internal Consistency Reliability (Cronbach Alpha Coefficient) and Discriminant Validity (Mean Correlation With Other Scales) for Two Units of Analysis for Pretest and Posttest for TOMRA

Scale	Unit of Analysis	No of Items	Alpha Reliability		Mean Correlation with other Scales	
			Pre	Post	Pre	Post
Enjoyment of Mathematics Lessons	Individual	8	0.95	0.95	0.38	0.38
	Class Mean		0.98	0.97	0.45	0.15
Attitude to Mathematical Inquiry	Individual	8	0.85	0.90	0.45	0.58
	Class Mean		0.81	0.96	0.53	0.44
Normality of Mathematicians	Individual	8	0.92	0.95	0.38	0.39
	Class Mean		0.94	0.98	0.44	0.56

The sample consisted of 914 students in 49 classes.

Table 4.4 shows that, with the student as the unit of analysis, the alpha reliability coefficient for the three TOMRA scales ranged from 0.85 to 0.95 for the individual unit of analysis for the pretest and from 0.90 to 0.95 for the posttest. The alpha reliability with these scales with the class mean unit of analysis ranged from 0.81 to 0.98 on the pretest, and from 0.96 to 0.98 on the posttest. These values indicate a high degree of internal consistency reliability for all TROFLEI scales.

4.2.4 Discriminant Validity of the TROFLEI and TOMRA

This section reports the discriminant validity of the TROFLEI and the TOMRA. For good discriminant validity, scales within the same questionnaire should not correlate highly with one another because they measure different constructs. For the purposes of this study, the mean correlation of a scale with the other scales in the same questionnaire was used as a convenient index of discriminant validity (again for the same two units of analysis).

Table 4.3 shows that, for the 10 TROFLEI scales, the mean correlation of a scales with the other scales ranged from 0.12 to 0.38 for the pretest with the student as the unit of analysis, from 0.15 to 0.39 for the posttest with the student as the unit of analysis, from 0.24 to 0.61 for the pretest with the class mean as the unit of analysis, and from 0.27 to 0.61 for the posttest with the class as the unit of analysis. Overall, these values are low enough to indicate satisfactory discriminant validity and that raw scores on the 10 TROFLEI scales measure independent, but somewhat overlapping, aspects of classroom environment. Furthermore, the factor analysis results in Table 4.1 support the independence of factor scores on the TROFLEI.

As shown in Table 4.4, the three eight-item TOMRA scales used in this study demonstrated reasonable discriminant validity for both units of analysis. For the individual unit of analysis, the mean correlation with other scales for the individual unit of analysis ranged from 0.38 to 0.45 for the pretest and from 0.38 to 0.58 for the posttest. For the class mean unit of analysis, mean correlations ranged from 0.44 to 0.53 for the pretest and from 0.15 to 0.56 for the posttest.

4.2.5 Ability of TROFLEI to Differentiate Between Classrooms

The ability of the TROFLEI to differentiate between classes is an important and valuable characteristic for a classroom environment instrument (but is not relevant for the attitude questionnaire). While students within the same classroom should have similar perceptions of that classroom, students' perceptions should be different from classroom to classroom. Given the data available, I undertook ANOVA to check the ability of each TROFLEI scale to differentiate between the perceptions of students in different classrooms. Table 4.3 shows the ANOVA results for each TROFLEI scale for the posttest when class membership was used as the independent variable. The eta^2 statistic, which is the ratio of the 'between' to 'total' sum of the squares, represents the proportion of variance explained by class membership for each TROFLEI scale.

Table 4.3 shows that every TROFLEI scale demonstrated significant differences ($p<0.01$) between classrooms. Values of eta^2 ranged from 0.08 for Student Cohesiveness to 0.25 for Teacher Support.

4.2.6 Summary of Validity Results

Overall the results reported in Tables 4.1–4.4 support the factorial validity, internal consistency reliability, and discriminant validity of the TROFLEI and TOMRA, as well as the ability of the TROFLEI to discriminate between classrooms (with this characteristic not being relevant for the TOSRA). These results with my sample of 914 mathematics students in Florida replicate the findings of the limited number of prior validations of the TROFLEI reviewed in Section 2.2.2.10. These previous validations involved samples of 2137 Australian students (Aldridge & Fraser, 2008), 1249 Australian students (Dorman & Fraser, 2004), 980 students in Turkey and 130 students in the USA (Welch, Cakir, Peterson & Ray, 2012), and 1027 students in New Zealand (Koul, Fisher & Shaw, 2011).

Furthermore, my findings replicate the validity and reliability results for the TOMRA in prior studies with samples of mathematics students (Ogbuehi & Fraser, 2007; Spinner & Fraser, 2005), as well as considerable prior research involving the use of TOSRA with science students (Fraser, 1981a; Fraser, Aldridge, Adolphe, 2010; Wong & Fraser, 1996). Further details about the validity of TOMRA/TOSRA in past research can be found in Section 2.3.

4.3 Evaluation of the FCAT Explorer

For Research Question 2, involving an evaluation of the FCAT Explorer in terms of classroom environment and student attitudes, differences between pretest and posttest scores for the 10 TROFLEI and three TOMRA scales were investigated using effect sizes and MANOVA with repeated measures. The interval between pretest and posttest was 10 weeks.

Table 4.5 Average Item Mean, Average Item Standard Deviation, Difference between Pretest and Posttest (Effect Size and ANOVA Results) for Classroom Environment and Student Attitude Scales

Scale	Average Item Mean		Average Item Standard Deviation		Difference	
	Pre	Post	Pre	Post	Effect Size	*F*
Learning Environment						
Student Cohesiveness	4.42	4.43	0.62	0.69	0.02	0.47
Teacher Support	3.56	3.49	0.97	0.98	-0.07	7.06**
Involvement	2.93	3.05	1.07	1.09	0.11	11.22**
Investigation	3.28	3.35	0.94	0.97	0.07	5.06*
Task Orientation	4.47	4.41	0.59	0.68	-0.09	8.55**
Cooperation	3.87	3.81	0.81	0.83	-0.07	4.93*
Equity	4.33	4.23	0.82	0.90	-0.12	16.32**
Differentiation	2.34	2.41	0.95	1.06	0.07	6.55*
Computer Usage	2.05	2.14	0.94	1.07	0.09	6.55*
Young Adult Ethos	4.19	4.19	0.80	0.80	0.00	0.00
Attitudes						
Enjoyment	2.94	3.02	0.50	0.52	0.16	3.04
Inquiry	2.77	2.70	0.32	0.42	-0.19	1.36
Normality	2.63	2.56	0.43	0.49	-0.15	1.46

*$p<0.05$, **$p<0.01$
The sample consisted of 914 students in 49 classes

Table 4.5 shows for each TROFLEI and TOMRA scale the average item mean, average item standard deviation, and the difference between the pretest and posttest (effect size and ANOVA results). For the pretest environment scales, the average item mean ranged from 2.05 to 4.47, and it ranged from 2.14 to 4.43 for the posttest. For the pretest attitude scales, the average item mean ranged from 2.63 to 2.94, and it ranged from 2.56 to 3.02 on the posttest.

A MANOVA with repeated measures was conducted for the pretest–posttest changes in the set of 13 learning environment and attitude scales. Because the multivariate test using Wilks' lamda criterion revealed statistically significant pre–post differences for the whole set of independent variables, the results for the individual ANOVA with repeated measures were interpreted for each of the 13 scales.

The ANOVA results in Table 4.5 show that pre–post differences were statistically significant for 8 of the 10 learning environment scales and for none of the attitude scales. Over the time when FCAT Explorer was used, students perceived significantly more Involvement, Investigation, Differentiation and Computer Usage, but significantly less Teacher Support, Task Orientation, Cooperation and Equity.

This analysis of pre–post differences provides insights into the specific areas in which students' perceptions of classroom environment changed significantly over the 10-week period during which the FCAT Explorer was used. A review of some of the items included in the relevant scales lends credence to the plausibility of the statistically significant results. Scales for which there was a significant increase in scores between pretest and posttest included items such as “Students discuss with me how to go about solving problems” (Involvement), “I carry out investigations to answer questions that puzzle me” (Investigation), “I work at my own speed” (Differentiation), and “I use the computer to type my assignments” (Computer Usage). Sample items from the scales for which there was a significant decrease in scores between pretest and posttest include “The teacher helps me when I have trouble with my work” (Teacher Support), “I know how much work I have to do” (Task Orientation), “I share my books and resources with other students when doing assignments” (Cooperation), and “I am treated the same as other students in this class” (Equity). Nevertheless, despite the statistical significance of the pre–post differences for some scales, it is important also to consider the effect size or magnitude of any difference (see below).

Table 4.5 also provides the effect size for each scale to portray the magnitude of pre–post differences. The effect size, which is the difference between pretest and posttest means expressed in standard deviation units, is calculated by dividing the difference between means by the pooled standard deviation.

The effect sizes for the pre–post differences for different scales in Table 4.5 range in magnitude from 0.00 to 0.19 standard deviations and are all classified as small according to Cohen's (1988) criteria. Moreover, changes between pretest and posttest represent an increase in scores for 6 scales, a decrease in scores for 6 scales, and a zero change for 1 scale.

Overall, in terms of pre–post changes for the learning environment and attitude scales used in my study, Table 4.5 suggests that the use of FCAT Explorer provided neither much advantage nor much disadvantage. Although the learning environment seemed to improve a little on some TROFLEI scales, it also deteriorated a little on some other learning environment scales.

My finding that there was little advantage or disadvantage to using FCAT Explorer seems consistent with the 'no significant difference phenomenon' (Russell, 1999) associated with using many forms of technology-assisted instruction as discussed in Chapter 2, Section 2.4.5. Over the last century, research on numerous technological enhancements to education – including loudspeakers, phonographic recordings, instructional radio, television, electronic blackboard, e-reader/tablet devices, and other computer-assisted content delivery software programs – has revealed no significant differences. Therefore, as discussed further in Chapter 5, the results of my study further contribute to the pattern that technology alone is not the key to improving education (in terms of learning environment and student attitudes in this research).

4.4 Attitude–Environment Associations

Research Question 3, involving attitude–environment associations, was answered using the techniques of simple correlation and multiple regression analyses. Regression weights were used to describe the association between each TROFLEI scale and each TOMRA scale when the scores on the other nine TROFLEI scales were mutually controlled. The same sample of 914 students in 49 classes was used for these analyses. The 10 scales of the TROFLEI provided measures of classroom environment, whereas the three TOMRA scales provide measures of students' attitudes to mathematics.

The simple correlation analysis provided the bivariate association between each student attitude outcome and each learning environment scale separately for the pretest and postest data. Table 4.6 shows that a positive and statistically significant correlation ($p<0.05$) emerged between one of the student attitude scales and some of the 10 learning environment scales for 47 out of 60 cases (78%) with the individual as the unit of analysis and for 28 out of 60 cases (47%) with the class as the unit of analysis. Further, the data showed similar results for the pretest and postest data.

Multiple regression analysis was undertaken using the set of 10 scales of the TROFLEI as independent variables and one of the science attitudes scales as the dependent variable. This analysis provided a more parsimonious picture of the joint influence of the set of correlated environment scales on each attitude outcome and reduced the Type I error rate. A multiple regression analysis was performed separately using the individual student and the class mean as the units of analysis.

Table 4.6 shows that multiple correlation (R) between the set of 10 learning environment scales and each of the three attitude scales was statistically significant ($p<0.01$) with either the individual or the class mean as the unit of analysis. The results for the pretest and posttest were similar.

To interpret which the TROFLEI scales contributed to the statistically significant multiple correlations, the standardized regression weights displayed in Table 4.6 were examined. The regression weights (β) show the association between an attitude scale and a particular TROFLEI scale while controlling for the effect of the other nine TROFLEI scales.

For the attitude scale of Enjoyment of Lessons, Table 4.6 shows the following statistically significant multivariate associations with learning environment scales:

- Teacher Support and Investigation were significant independent predictors of Enjoyment with the student as the unit of analysis for the pretest.
- Teacher Support, Equity, Differentiation and Computer Usage were significant independent predictors of Enjoyment with the student as the unit of analysis for the posttest.
- Equity and Young Adult Ethos were significant independent predictors of Enjoyment with the class as the unit of analysis for the posttest.
- Involvement, Investigation, Task Orientation, Equity and Young Adult Ethos were significant independent predictors of Enjoyment with the class as the unit of analysis for the posttest.

For the Attitude to Inquiry scale, Table 4.6 shows the following statistically significant multivariate associations with learning environment scales:

- Investigation and Computer Usage were significant independent predictors of Inquiry with the student as the unit of analysis for the pretest.
- Investigation and Equity were significant independent predictors of Inquiry with the student as the unit of analysis for the posttest.
- Cooperation was a significant independent predictor of Inquiry with the class as the unit of analysis for the pretest.
- Equity was a significant independent predictor of Inquiry with the class as the unit of analysis for the posttest.

For the Normality of Mathematicians scale, Table 4.6 shows the following statistically significant multivariate associations with learning environment scales:

- Cooperation was a significant independent predictor of Normality with the student as the unit of analysis for the pretest.
- Teacher Support, Equity, Differentiation and Computer Usage were significant independent predictors of Normality with the student as the unit of analysis for the posttest.
- Cooperation was a significant independent predictor of Normality with the class as the unit of analysis for the pretest.
- Investigation was a significant independent predictor of Normality with the class as the unit of analysis for the posttest.

Table 4.6 Simple Correlation and Multiple Regression Analyses for Associations Between Student Attitudes and Classroom Environment for Two Units of Analysis

Scale	Unit of Analysis	Enjoyment				Inquiry				Normality			
		r		*β*		*r*		*β*		*r*		*β*	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Student Cohesiveness	Individual	0.11**	0.09**	0.06	-0.04	0.05	0.04	-0.02	-0.02	0.04	0.04	-0.06	-0.04
	Class	0.03	-0.03	0.19	-0.16	0.21	0.46	0.11	0.04	0.14	0.43	0.02	-0.01
Teacher Support	Individual	0.13**	0.18**	0.09*	0.13**	0.11**	0.12**	0.00	0.04	0.15**	0.18**	0.06	0.13**
	Class	0.49**	0.62**	0.08	0.08	0.59**	-0.06	-0.04	0.18	0.61**	0.16	0.17	0.46
Involvement	Individual	0.10**	0.13**	0.00	-0.02	0.09**	0.06*	0.01	-0.03	0.08**	0.06*	-0.01	-0.02
	Class	0.58**	0.58**	0.31	0.39*	0.55**	-0.12	0.11	-0.11	0.61**	0.03	0.32	0.11
Investigation	Individual	0.12**	0.13**	0.09*	0.00	0.14**	0.13**	0.10*	0.11**	0.09**	0.08**	0.00	0.00
	Class	0.49**	0.51**	0.01	0.40*	0.52**	-0.19	0.16	-0.04	0.54**	-0.12	0.14	0.55**
Task Orientation	Individual	0.08**	0.09**	0.01	0.01	0.08**	0.12**	0.00	0.01	0.07**	0.14**	-0.04	0.01
	Class	-0.11	0.58**	0.05	0.54**	0.12	-0.11	-0.01	0.27	0.11	0.02	-0.14	0.28
Cooperation	Individual	0.13**	0.13**	0.05	0.01	0.12**	0.08**	0.08	0.01	0.17**	0.08**	0.15**	0.01
	Class	0.04	0.06	0.03	0.29	0.37**	0.59**	0.48**	0.31	0.37**	0.59**	0.35*	0.26
Equity	Individual	0.11**	0.15**	0.03	0.11*	0.11**	0.16**	0.05	0.10*	0.15**	0.21**	0.06	0.11*
	Class	0.62**	0.63**	0.38*	0.36*	0.57**	-0.23	0.34	0.63**	0.52**	-0.02	-0.01	-0.31
Differentiation	Individual	0.01	-0.01	0.00	-0.09*	0.01	-0.08**	0.03	-0.04	-0.03	-0.14**	-0.03	-0.09*
	Class	0.12	-0.41**	0.13	0.31	-0.07	0.30	0.00	0.14	-0.01	0.16	0.06	0.07
Computer Usage	Individual	0.00	-0.05	-0.03	-0.10**	0.04	-0.09**	-0.08*	-0.08	-0.05	-0.16**	0.06	-0.10**
	Class	-0.23	-0.46**	-0.25	-0.11	-0.36**	0.19	-0.26	0.19	-0.24*	0.06	-0.13	0.01
Young Adult Ethos	Individual	0.08**	0.08**	-0.03	0.04	0.09	0.12**	0.00	0.00	0.15**	0.15**	0.07	0.04
	Class	-0.07	0.02	0.44**	0.39*	0.24*	0.54**	-0.39	0.33	0.29*	0.54**	0.06	0.28
Multiple Correlation, *R*	Individual			0.17**	0.28**			0.18**	0.20**			0.22**	0.28**
	Class			0.73**	0.74**			0.62**	0.65**			0.69**	0.68**

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

The sample consisted of 914 students in 46 classes.

It is noteworthy that most of the statistically significant bivariate (*r*) and multivariate (β) associations in Table 4.6 are positive, suggesting that higher levels of the classroom environment dimensions in the TROFLEI were associated with more positive student attitudes on the three scales of Enjoyment, Inquiry and Normality. This pattern replicates considerable prior research reviewed by Fraser (2012, 2014) and in Chapter 2 of this thesis.

However, it is also noteworthy that Table 4.6 reveals the existence of statistically significant negative associations between the TROFLEI scales of Differentiation and Computer Usage and all three student attitude scales of Enjoyment, Inquiry and Normality. That is, greater emphasis on differentiating classroom instruction and more frequent use of computers was associated with less enjoyment and less positive attitudes among students.

Because FCAT Explorer involves the delivery of the curriculum via an internet-based computer program, the classrooms in my study were characterized by varying levels of individualization (Differentiation) and computer use (Computer Usage) that were typically higher than for conventional classrooms that emphasize whole-class activities and teacher–student interactions. However, my findings in Table 4.6 suggest that students enjoyed mathematics less and held less positive attitudes in classrooms with higher levels of Differentiation and Computer Usage. This possibly suggests that, in classes where FCAT Explorer is used, students enjoyment would be enhanced by providing more opportunities for whole-class interaction and more student–teacher interaction. Furthermore, past research has revealed this pattern in which more classroom Differentiation was associated with more negative student attitudes (e.g. Fraser & Fisher, 1982).

4.5 Findings Based on Qualitative Data Collection

In Chapter 3, Section 3.6, I discussed how my study involved a minor yet important component of qualitative data collection based on student interviews. In the subsections below, I describe the collection of my interview data (Section 4.5.1) and report findings based on these qualitative data in two different ways involving a narrative (Section 4.5.2) and an analysis of themes (Section 4.5.3).

4.5.1 Qualitative Data Collection

Quantitative data provide statistical information that helps us to understand a research question. Growing in popularity is the use of a qualitative component so that the questions in the study can be answered with a more real-world fabric. While quantitative data have long been the cornerstone of academic research, qualitative research methods have added valuable insights to the quantitative findings. A potent example of the value of qualitative data was demonstrated in Fraser's (1999) multilevel learning environment study that offered perspectives from a teacher–researcher as well as a group of six researchers. The study included multiple classroom visits over a five-week period, student–administrator–parent interviews, student diaries, and video footage.

As discussed in Section 3.6, qualitative data based on interviews were employed in my study to help to substantiate and embellish the findings based on my quantitative questionnaire data. Combining the two techniques of quantitative and qualitative data collection has been advocated and used successfully in learning environments research (Aldridge, Fraser, & Huang, 1999; Fraser & Tobin, 1991; McKnight et al., 2000; Tobin & Fraser, 1998). Although qualitative data collection played a less prominent role in my research than did quantitative data collection, nonetheless, the qualitative component still was important.

Although it is not intended to undertake a comprehensive review of past qualitative studies in this section, it is important to elaborate several qualitative methods that were used in my study. Interviews were conducted in Singapore (Khoo & Fraser, 2008) to more deeply probe student questionnaire responses. In Brunei (Khine & Fisher, 2001), interviews were used to illuminate with participants the issues emerging from a survey. In another Singaporean study (Wilks, 2000), interpretive and narrative methods were used in conjunction with administration of the Constructivist Learning Environment Survey in investigating the consistency of teaching and learning with critical constructivism.

The purpose, then, of using a qualitative data collection in my study was to investigate the level of consistency between students' responses to questionnaires and their interview responses. Qualitative data collection for this study consisted of a series of questions posed in a personal interview format. With the interview format, I was able to determine, in addition to consistency, the reasons for student responses to the questionnaire. Students were invited to participate in the interviews on a voluntary basis and they were chosen based upon their achievement scores in their current class, with some students from the upper achievement quartile, some from the middle quartiles and some from the lowest quartile. A total of 24 students were interviewed over the course of three weeks after the program FCAT Explorer was completed. Of the 24 students, 9 were male and 15 female. There were 3 students from the 7th grade and 21 students from the 8th grade.

Table 4.7 Sample Responses to Interview Questions

Scale	Question	Sample Response
Teacher Support	Describe things that your mathematics teacher does to help you to learn mathematics.	*"My mathematics teacher uses the FCAT Explorer program to help me learn."*
Investigation and Task Orientation	Describe how you solve mathematics problems.	*"I look at the problem and I think what the problem is asking for and what procedures I have to take to solve the problem. Then I solve the problem."*
Student Cohesiveness and Cooperation	How important is it to you to work with other students when you do mathematics?	*"It depends. Generally I'll talk more but sometimes I understand better when a student explains something."*
Computer Usage	Describe how you feel about using the computer to work on mathematics problems.	*"I don't really like it. I prefer using pencil and paper."*
Young Adult Ethos	Describe some things that you like about mathematics class.	*"In my mathematics class, I like the positive environment and I enjoy having a teacher to explain the problems and answer my questions."*
Open-Ended Attitude item	Describe the main way in which FCAT Explorer has changed your attitude about mathematics.	*"FCAT Explorer has changed my attitude about mathematics by reminding me that there is always more than one way to solve problems."*

Interview questions were designed based on the scales of both the TROFLEI and TOMRA. The scales considered in the interview questions were Teacher Support, Investigation and Task Orientation, Student Cohesiveness and Cooperation, Computer Usage, and Young Adult Ethos, with the final question allowing an open-ended response regarding the attitudes of Enjoyment of Lessons and Attitude to Inquiry. Table 4.7 shows each scale and the associated interview question posed to the students. Interview questions are provided in Appendix C.

Each interview followed the same format as closely as possible. The students were asked to be seated and then there were a few minutes of social conversation when I inquired about the students' health and comfort at that time, how their day had been, and if they were ready to answer a few questions about their mathematics class.

The first four questions were for background purposes, with assurances given that student names would not be published and that information of a personal nature wouldn't be required. The students were then asked their first name, grade, current mathematics class, and the classes they took during the previous year. For the next two questions, students responded with a description of what specific things that their mathematics teacher did to help them to learn mathematics and how they solved mathematics problems. The next question asked for their opinion about the importance of working with other students when doing mathematics. The next questions asked for a response about their feelings towards using a computer when working on mathematics problems. The next question, designed to bridge the gap between the learning environment and student attitudes, involved a description of some of the things that the student liked about mathematics class. The final question asked the student to summarize the main way in which using the FCAT Explorer program had changed their attitudes about mathematics.

The interviews lasted from 7 to 12 minutes, with the average time being approximately 9 minutes. The interviewer took notes of the conversation but, to preserve the student's thoughts more accurately, the student was asked to fill out the highlights of their thoughts on a questionnaire (Appendix C). This questionnaire mirrored the questions that the student had just been asked. The typical time to complete the written form was about 7 minutes. It is from the interviewer notes and student written responses that the qualitative data were drawn.

The qualitative data collection drew upon six core questions that related to the scales from the TROFLEI, with one of the questions allowing an open-ended response regarding attitudes towards mathematics that would potentially correspond to the attitude scales included in the modified TOMRA. Each response ranged from a single sentence to a paragraph. This provided a data set of 144 responses with the word-for-word response being the unit of analysis.

The presentation of these qualitative data posed a problem for the researcher because there are several ways to present the findings. One method is to provide a summary of the responses. A second method is to analyze the responses for recurring themes, and then to provide a tabulation of the emerging themes typically in columnar format (Taylor & Fraser, 2012); see Section 4.5.3 below. A third method of communicating insights from the interviews, reported in Section 4.5.2, involves the use of narrative stories.

4.5.2 Narrative

For this study, one method for presenting the findings was in the form of a narrative (Aldridge, Fraser, & Huang, 1999; Clandinin & Connelly, 1994) describing a visit by imaginary classroom observers who enter several classes as visitors from ‘out of town’ and chats with students as they are participating in class. Student responses are drawn from the interviews to provide a straightforward view of what was happening in the classroom. Each student was able to give his/her personalized answers to the questions and, while each student is different, themes began to emerge. These themes, which are incorporated into the narrative that follows, can be viewed as representative of the classrooms in this study even if all themes were not present in all classrooms at all times. The narrative, then, helped to establish a context for the classroom environment.

Visiting a Middle-Grades Mathematics Class in Florida

It is bright even at this early hour. The sun is streaming down on the white walls of the trailers that have been converted to classrooms. The sea-blue trim of the flashing around the upper edges of the building almost matches the sky. The concrete sidewalks are covered with aluminium roofing to offer a bit of protection from the sun on this day, and tropical downpours on other days. A smartly dressed couple in their mid-to late-thirties are walking purposefully up a ramp next to one of the white trailers towards the door that is painted the same blue as the building trim. Rapping sharply on the metal door, it bursts open with the enthusiasm of the child who has responded to the knock. The couple smile and say that they are here to see Mr. Earle. The child grins and, with a nod, backs away from the doorway to let the couple enter.

As they cross the threshold, they see that the door is at front left of the room, and directly in front of them is the teacher whom they are going to visit. He waves a greeting, motioning them to step to their right along the same wall the door is in, but he continues on with a lesson loudly using a picture of a fish tank that is being projected onto the room’s whiteboard, with an FCAT Explorer logo in the upper left corner of the picture. The couple are able to see the classroom from their vantage point on the side as they wait patiently for the lesson to finish.

The room is roughly 30 feet by 30 feet, blue linoleum one-foot squares covering the floor. The walls, at least the parts that are not covered by colourful posters of mathematical formulas and motivational mottos, are covered with a blond wood panelling. Florescent lights illuminate the room and are helped by the 6 large windows that allow the increasing sunlight to enter and compete for first place in the bright, cheery room. The students are sitting in individual desks, with metal frames, plastic seats and flat wood tops for the writing surface. The desks are, however, not in rows but in groups of four, with two students facing two other students, sitting side-by-side and face-to-face with the wooden surfaces touching two lateral edges to form a ‘four-pack’ of eager mathematics students. There are 8 four-student groups and one three-student group towards the back of the room. The four-packs are angled on both sides of the room such that the students left or right shoulder is pointed to the front of the room. This makes facing the teacher as simple as slightly turning one’s head toward the front.

Along the front of the room is a 16-foot long, 4-foot tall white board mounted mid-way up the wall. It serves both as a writing surface for the white-board markers as well as a screen upon which the ceiling-mounted LCD projector is displaying the current problem. Along both sides are book shelves that only rise 3 feet from the floor, with cubby holes that are filled with books, copy paper, and other teaching materials. Along the back of the room are several long tables that occupy the entire length of the back wall with the exception of the teacher desk at which the team teacher is currently seated. On these tables are 5 computers that look to be about 7 years old. All the screens are turned on and, once again, the FCAT Explorer logo is visible on the computer screens.

The couple are momentarily puzzled by the large number of students, remembering that, in 2005, Florida adopted a class-size limit of 24 students per class. This classroom has, by a quick count of the student groups, more students than required by the class-size mandate. But a glance towards the corner farthest from the entry door reveals another teacher, a stylishly dressed woman who exudes the posture and aura of a veteran teacher. Despite the law limiting the number of students per class, schools have discovered the loophole that allows the addition of another teacher thereby doubling the student audience. In this class, there are 35 students, and so walking space around the groups is at a premium. Students are raising their hands in answer to a question that the couple didn’t hear. A chorus of “I know, I know” is quickly ended when one student is chosen to provide the correct answer.

The problem discussion activity is drawing to a close and the teacher in the front, Mr. Earle, beckons the couple forward and greets them warmly. He then turns to the class and tells them that the couple are visiting from another country. Introductions are made.

“Class, this is Mr. O and Ms. F and they’d like to ask you a few questions about what we’re doing, what you’re doing and your thoughts about using computers to study mathematics,” says Mr. Earle. “We’ll start off with a question or two for the whole class, and then we’ll get to work on the assignment while Mr. O and Ms. F come around to chat with your group, Ok?” Another chorus of “Ok” is followed by an admonishment from Mr. Earle to shush, and the first question is tossed out to the students.

“First,” begins Mr. O, “Describe the things your mathematics teacher does to help you learn mathematics”. A wave of hands go up, and Mr. O points to a young man with dark hair in the front group.

“He teaches us!” Mr. O points to a student in the same group. “He teaches us and explains how to do the lesson after we try it ourselves.”

“Thank you,” says Mr. O. “Now how about you over here.” He points to an athletic looking young lady in a group to the left.

“He makes us answer our own questions which makes us more independent. He has the class do many hands-on activities. He also offers tutoring every morning and he creates songs to remember formulas. Isn’t that right, Nikki?” She turns to the tall student sitting next to her.

“He has us participate in many hands-on activities and he uses different teaching methods to accommodate different learning styles. And he shows us ways that mathematics is used in the real world.”

“Thank you again,” says Mr. O. “Now what we’d like to do is to ask that you students continue with your work and Mrs. F and I are going to come chat with your groups while you work.” The students look to Mr. Earle who points to the assignment on the board directing them to begin working on problem packets copied from the FCAT Explorer. The students shift into writing mode, and begin to work together on solving the collection of word problems. A buzz of relatively soft voices fills the room as the students go about problem solving. Mr. O begins to walk around the left side of the room to the second layer of groups while Mrs. F does the same on the right. Both lean down to groups on opposite sides of the room and ask the second question.

“Describe how you solve mathematics problems,” requests Mr. O. of the group of four students.

“I read it and try to solve it”, says one student.

“I digest the problem and then use the skills that were taught to me in order to solve it”, says a second student.

“The hard way,” says a young lady with a smile. “I use formulas and go step by step!”

Meanwhile, on the other side of the room, Mrs. F has posed a different question.

“How important is it to you to work with other students?” she asks.

“It really helps me because, if I am doing it wrong, someone is there to tell me. It also helps me to find easier ways to compare problems,” says the student with her back to the window.

“It is very important. It is a learning experience and, when you work with others, it makes you realize what mistakes you made and the concepts stick better,” says the girl sitting across from her.

“It depends,” says a third girl in the group with a thoughtful look on her face. “Generally I’ll talk more but sometimes I understand better when a student explains something to me.”

Both Mr. O and Mrs. F thank the groups and move to the last row of groups in the back of the room and pose a new set of questions. Mr. O’s group looks up expectantly as he approaches them.

“Describe how you feel about using the computer to work on mathematics problems,” he requests. The students fall silent for a few seconds and a few of them exchange glances. One shy young lady answers Mr. O.

“I prefer working on paper because I feel that I can expand more, but computer work is good too,” she says softly, her face searching for approval.

“Don’t worry,” says Mr. O. “There are no right answers, and this is not for a grade. We are just trying to get a clearer picture about what you experienced by talking directly with you.”

A visible look of relief passes over the students’ faces and a young man immediately jumps into the conversation.

“I hate using the computer when it comes to mathematics problems,” he states firmly without a hint of a smile. “You have to take up a lot of space, and it becomes confusing.”

“Yes,” agrees a young lady sitting across from him. “Using the computer to work on mathematics is more difficult for me. I would rather read it on paper. Having the question on the computer makes me feel that I can’t work out the problem to the full potential.”

“I kind of disagree,” says the fourth member of the group, a slight girl with long dark hair wearing red-framed glasses. “Living in this technological era, I personally think that the integration of a computer with mathematics is a motivational suggestion to learning mathematics. I learn a lot more online. When I don’t understand something, I can go on another website for help.”

One group over, Mrs. O has engaged the only three-member group in a conversation. She has asked them to describe some of the things that they like about mathematics class.

“In my mathematics class, I like the positive environment and I enjoy having a teacher to explain the problems and answer my questions. I like the fact that we’re always working in groups and that we get to present some of the lessons to the class,” says one of the girls.

“That’s true,” says another girl who leans forward excitedly. “What I like about it is that you get to use your head a lot. I love working out problems with formulas. Also, I get to interact with my classmates. And I like how involved Mr. Earle is with us, and I also like how simple a topic seems once you understand it!”

“Mathematics class may not be fun,” says the third group member, a serious young lady a determined set to her jaw. “But I’m very confident of the fact that I have learned a lot this year, and I know I passed the FCAT.”

With a thank you to the student groups, both Mr. O. and Mrs. F. turn to the back of the room where four students are working on the FCAT Explorer while the class is going on.

“Hello, are you working on the Explorer?” asks Mr. O.

"Yes," says the first student who glances up momentarily from the screen. "We get about 15 minutes to work on the computer and then we go back to our desks so other students can take a turn."

"I see," says Mr. O. "Has the FCAT Explorer changed your attitude about mathematics?"

The first student looks thoughtful and then replies, "Yes, I think the FCAT Explorer has changed my attitude about mathematics by reminding me that there is always more than one way of solving problems, but I believe that test practice was a more successful way to learn."

The student sitting next to her was listening and then added, "Now I feel that questions are more a subject of reading than mathematics. And because FCAT Explorer gives you a lot of second chances, it made me very lazy and a lot of times I just guessed and I was getting good scores."

Mr. O's eyes widen with surprise at this response. He glances over to Mrs. F and they both thank the students and turn to the final two groups in the centre of the class. Mr. O gets the attention of both groups and poses the last request.

"Here is our final question. You all used the FCAT Explorer for almost 3 months this year to prepare for the FCAT test. Describe the main way using FCAT Explorer has changed your attitude about mathematics."

One young lady was quick to raise her hand with an answer. "The FCAT Explorer helped me a lot by showing me what I do wrong while solving problems. It also shows me the steps to solving after I finish so that I can check if I used the right steps."

"With FCAT Explorer, I realized that mathematics can be used for many things. Mathematics can be used to solve real-life problems. I think the FCAT Explorer challenged me and made me think. It made me realize how many different ways numbers can be used. So I have a greater appreciation for it," answers another student.

But not all students were so quick to praise the program. "I do not believe it was very helpful. If anything, it has made tedious and boring. I didn't like FCAT Explorer."

The level of noise began to grow in the classroom and both Mr. O and Mrs. F came to the front of the class to say thanks and take their leave.

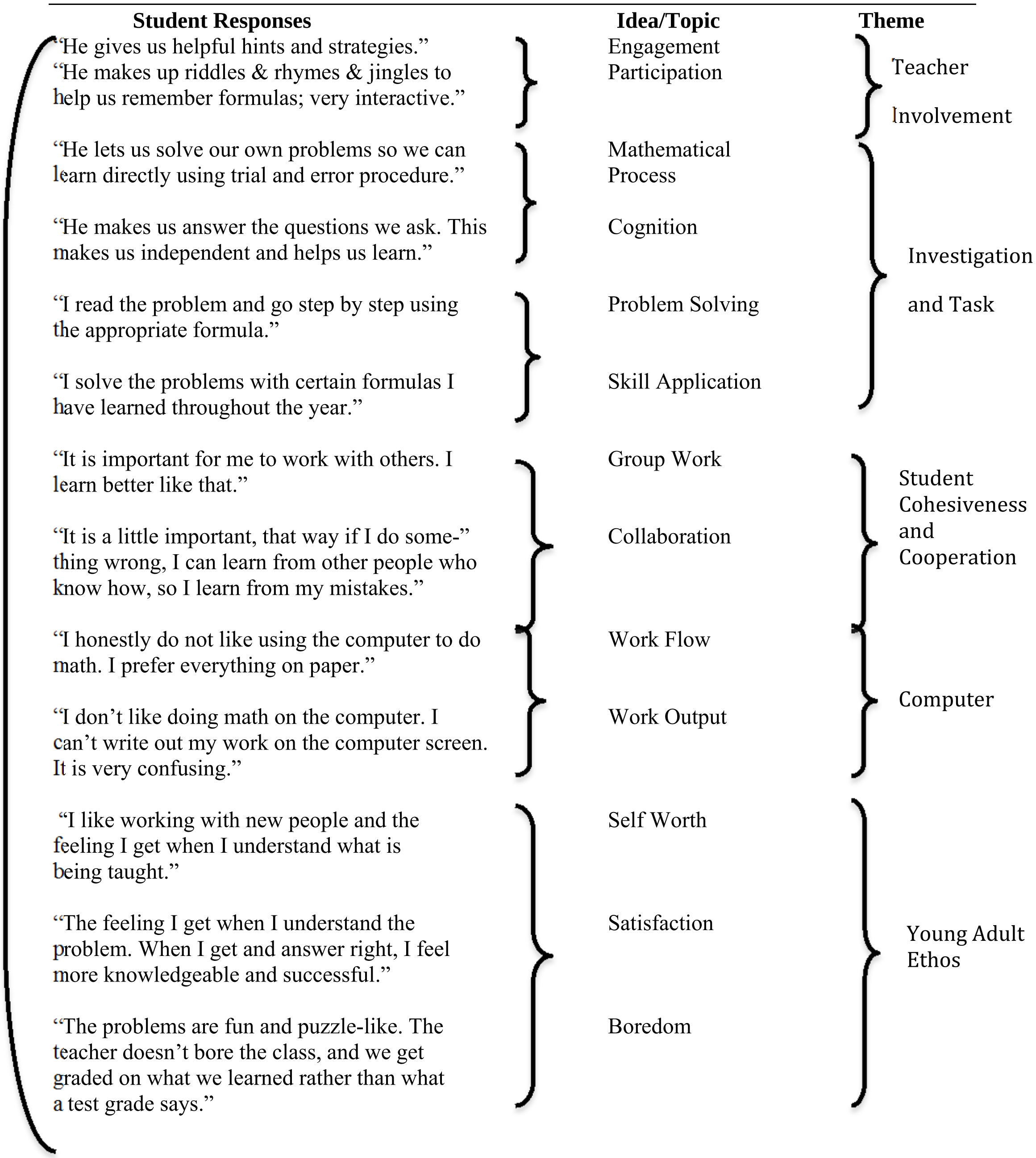
4.5.3 Thematic Analysis of Interview Responses

The above narrative contained the words from the interviewed students verbatim. While giving a sense of the students' perceptions of their environment in their own words, there seemed to be resurgent themes that could be categorized. Using a scheme of coding data that leads to linking to an idea or topic that then leads to a theme (Richards & Morse, 2007), an inductive process was used similar to a conceptual factor analysis. The initial unit of analysis is the word-for-word response from the students for each of the topics posed to them.

The analysis of the interview response data involved a method documented by several researchers (Patton, 1992; Silverman, 2000; Taylor & Fraser, 2013). This technique uses themes that develop from the interview responses and combines those themes into higher-order groupings of the main conceptual ideas of those themes. This forms an analysis structure of three levels. The first level is the student response, or the initial unit of analysis. The second level begins to combine responses in a higher-order grouping of the responses. I refer to this second level as the Idea/Topic level. The Idea/Topic level can be compared with factor analysis of quantitative data, but involves examining concepts. From this second level, I identified themes that took on the expected form of the constructs used as scales in the TROFLEI and TOMRA. Again, the total number of quotes gathered for this sample was 144 responses of varying length. Figure 4.1 shows the linked analysis.

As students reflected on their tasks, their process of learning, and their perceptions of what was happening, several common Idea/Topics emerged. The first Idea/Topic consisted of responses that related to Engagement. This concept included activities that students found interesting, such as ‘helpful hints and strategies’ and ‘riddles, rhymes and jingles’. The second Idea/Topic was derived from responses that related to what I refer to as the Mathematical Process in which students identify the way in which they approach mathematics. This Idea/Topic included such process-oriented responses as ‘learn directly using trial and error’ and ‘answering our own questions’. The next Idea/Topic included responses in which the students identified that problem-solving process in a more concrete, methodical way such as ‘I read the problem and solve it going step-by-step’ and ‘I use formulas to solve the problem’. The next Idea/Topic was derived from responses that described how students felt about working together. Some samples for this Idea/Topic included ‘it is important for me to work with others’ and ‘I learn better when I work with others’.

The next Idea/Topic addressed a central theme of this research project, namely, how students felt about using the computer. I referred to this Idea/Topic as Work Flow because, apart from the educational content presented to the students, they also responded conceptually to the computer as the tool that they used when undertaking their mathematical work. Responses included some rather pronounced feelings such as ‘I don’t like using the computer to do mathematics’, ‘I prefer pen and paper’, and ‘it’s very confusing’. The last Idea/Topic combined responses in which students described their internal feelings of self in the context of doing mathematics. I call this Self Worth and comments included ‘I like the feeling I get when I understand what is being taught’ and ‘I like being graded on what we learn’.



Student Responses	Idea/Topic	Theme
“He gives us helpful hints and strategies.” “He makes up riddles & rhymes & jingles to help us remember formulas; very interactive.”	Engagement Participation	Teacher Involvement
“He lets us solve our own problems so we can learn directly using trial and error procedure.”	Mathematical Process	Investigation and Task
“He makes us answer the questions we ask. This makes us independent and helps us learn.”	Cognition	
“I read the problem and go step by step using the appropriate formula.”	Problem Solving	
“I solve the problems with certain formulas I have learned throughout the year.”	Skill Application	
“It is important for me to work with others. I learn better like that.”	Group Work	Student Cohesiveness and Cooperation
“It is a little important, that way if I do some-” thing wrong, I can learn from other people who know how, so I learn from my mistakes.”	Collaboration	
“I honestly do not like using the computer to do math. I prefer everything on paper.”	Work Flow	Computer
“I don’t like doing math on the computer. I can’t write out my work on the computer screen. It is very confusing.”	Work Output	
“I like working with new people and the feeling I get when I understand what is being taught.”	Self Worth	Young Adult Ethos
“The feeling I get when I understand the problem. When I get and answer right, I feel more knowledgeable and successful.”	Satisfaction	
“The problems are fun and puzzle-like. The teacher doesn’t bore the class, and we get graded on what we learned rather than what a test grade says.”	Boredom	

Figure 4.1 Analysis of Student Responses by Idea/Topic and Theme

Taking these Idea/Topics to a higher conceptual level was the next step. Because the purpose of the qualitative section of this research was to determine the consistency of students' verbal responses with the quantitative data. The Idea/Topics were guided by the questions posed to the students, and they fall rather conveniently into the scales of the TROFLEI, and therefore still fit with the intent of this research project. In reviewing Figure 4.1, a link can be made between the Idea/Topics and the Themes. In this study, the Themes correspond to the scales of the TROFLEI. Engagement and Participation correspond to Teacher Involvement. Mathematical Process, Cognition, Problem Solving and Skill Application correspond to Investigation and Task. Group Work and Collaboration fit well with the theme of Student Cohesiveness and Cooperation. The Idea/Topics of Work Flow and Work Output correspond to the TROFLEI theme of Computer. Self Worth, Satisfaction, and Boredom can be linked to Young Adult Ethos.

One item of note is that the reaction of the students to using the computer in the context of doing mathematics was almost universally negative. This negative response is consistent with the simple correlation and multiple regression analysis of a attitude associations presented in Table 4.6 which shows a negative association for several of the environment scales with the attitude scale of Enjoyment of Mathematics.

4.6 Summary

This chapter reported analyses and results associated with my quantitative questionnaire data, commencing with the validity of the TROFLEI and TOMRA when used in technology-supported classroom learning environments for middle-school mathematics students. This chapter also reported the analyses and results for the effectiveness of the FCAT Explorer in terms of changes over time in students' attitudes towards mathematics and their perceptions of their classroom learning environment. Also reported in this chapter were the associations between students' perceptions of technology-supported classroom environments and their attitudes towards mathematics. Finally, this chapter reported the results of a qualitative data analysis in two formats. First, a narrative portrayed student interview responses in a classroom setting. Second, I conducted a tier analysis of responses in a hierarchical format through two progressively higher-order analyses ending with scales of the TROFLEI presented as conceptual themes.

Classroom learning environment was assessed with the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI), which owes its pedigree to the What Is Happening In this Class? (WIHIC), whereas students' attitudes were assessed with the Test of Mathematics-Related Attitudes (TOMRA). These questionnaires were revised slightly to ensure their suitability for American middle-school mathematics students and their applicability specifically to mathematics classrooms. The data collected from 914 students in 49 classes were statistically analysed to answer my study's three research questions.

After the removal of 14 TROFLEI items during factor analysis, factor loadings for every item in the refined version of the TROFLEI containing 66 items in the original 10 scales were greater than 0.40 on their own scale and less than 0.40 on each of the other nine TROFLEI scales. For the three TOMRA scales, every item's factor loading was greater than 0.40 on its own scale and less than 0.40 on each of the other two scales. The proportion of variance accounted for by the TROFLEI scales was 50.94% (pretest) and 57.14% (posttest) and by the TOMRA was 58.22% (pretest) and 65.32% (posttest).

The alpha reliability coefficient for the 10 different TROFLEI scales with the individual as the unit of analysis ranged from 0.76 to 0.97 for the pretest and from 0.83 to 0.93 for the posttest, and for the three TOMRA scales ranged from 0.85 to 0.95 with the individual as the unit of analysis for the pretest and from 0.90 to 0.95 for the posttest. These values indicate a high degree of scale internal consistency reliability. Overall, the results supported the factorial validity and reliability of the TROFLEI and TOMRA for assessing classroom environment perceptions among middle-school mathematics students in Miami-Dade County, Florida.

When MANOVA was used to evaluate the effectiveness of using FCAT Explorer in terms of changes over 10 weeks in scores on learning environment and attitude scales, statistically significant changes emerged for some TROFLEI scales but not for the attitude scales. However, for the scales for which pre–post changes were statistically significant, changes were in the positive direction for some scales and in the negative direction for others. Moreover, the magnitude of the pre–post changes was small for every TROFLEI and TOMRA scale according to Cohen's (1968) criteria. Apparently, the use of FCAT Explorer was neither advantageous nor disadvantageous for this group of students. This finding of a lack of effectiveness associated with the use of technology is consistent with reviews of considerable past research by Russell (1999) and other researchers (see Chapter 2, Section 2.4.5).

Simple correlations and multiple regression analyses for two units of analysis (individual and class mean) were used to investigate associations between students' perceptions of the learning environment (TROFLEI) and their attitudes to mathematics (TOMRA). Past research (Fraser, 2012) was replicated in that there were positive and statistically significant bivariate and multivariate associations between each of the student attitude scales and most learning environment scales. However, associations with attitudes were consistently negative for the two TROFLEI scales of Differentiation and Computer Usage.

The collection of quantitative data based on learning environment and attitude scales was supplemented by some qualitative data gathering involving interviews with 24 students with questions about five learning environment constructs. Findings based on this qualitative information were reported using, firstly, a narrative and, secondly, an analysis of themes.

For the interview data, a thematic analysis similar to factor analysis was conducted using 144 interview responses in verbatim form. From this initial analysis, I derived 13 emergent Ideas/Topics which then linked to five TROFLEI scales. The qualitative data supported the quantitative findings for both positive as well as negative associations with student attitudes, with the most notable being a consistently negative response towards the use of computers when undertaking mathematical work.

In the next chapter, a discussion of the findings is provided. In addition, the contributions made by this study, as well as possible limitations of the study and suggestions for future research, are discussed.

Chapter 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

In the USA, high-stakes testing currently is a fact of life for students and teachers alike. The need to have ever-higher performances by students and, indeed, performances that can be linked to specific teachers is a trend that is permeating the education field. School districts are incurring large expenditures for textbooks, technology, and software that can potentially help student performance. The question arises as to the effectiveness of these materials, particularly the online mathematics program FCAT Explorer. Measuring students' perceptions of their classroom environment and their attitudes in the context of a mathematics program was the focus of this research.

My study made a practical contribution by providing evidence about the effectiveness of FCAT Explorer, but it also contributed to the learning environment field for several reasons. First, I was able to provide additional validation data for the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) and the Test of Mathematics Related Attitudes (TOMRA). Second, my study provided the largest sample size to date for research using the TROFLEI in the United States. The third reason is that my study represented the first time that a learning environment instrument had been used to provide criteria for evaluating FCAT Explorer.

Section 5.2 of this chapter contains a summary of Chapters 1 to 3 of this thesis. Section 5.3 summarizes the findings of my research organized in terms of its three research questions. Section 5.4 provides a discussion of some of the inevitable limitations that arise in any research in general and in my study in particular. Growing out of these limitations, Section 5.5 provides some suggestions for desirable directions that future research could take. Contributions to the field of learning environments and practical implications associated with this study are discussed in Section 5.6. Section 5.7 provides a few final thoughts.

5.2 Summary of Chapters 1–3 of the Thesis

My research provided the first use of learning environment tools to provide criteria for evaluating this online mathematics curriculum software. In the subsections below, a summary of Chapters 1–3 is provided in Sections 5.2.1 – 5.2.3.

5.2.1 Summary of the First Chapter Devoted to Introduction and Context

Section 1.1 of Chapter 1 provided an introduction, including a description of the online program FCAT Explorer, a mathematics software program for preparing students in grades 3 to 11 for the FCAT test. The idea of designing a study that directly compares the achievement of students using FCAT Explorer with the achievement of other students was rejected for a variety of reasons, not the least of which were issues with privacy, access to technology, and arriving at measureable design criteria. Instead, my research design included the use of the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI), an instrument that measures student perceptions of the classroom learning environment, and the Test of Mathematics Related Attitudes (TOMRA), which measures students' attitudes to mathematics in the context of the FCAT Explorer.

Section 1.2 described the school district in which the study took place, as well as the specific school site. This district is the fourth-largest school district in the United States, with an overall enrolment of approximately 350,000 students, two-thirds of whom are of Hispanic background. Also provided were details regarding the school where this study was conducted. Herbert A. Ammons is one of 60 middle schools in the district and has a student population of 1150 students who participate in a school-wide International Baccalaureate Middle Years Program (IBMYP), a program that includes a rigorous, eight-class schedule, including foreign language and performance arts requirements. A brief description of a typical student schedule is provided along with a partial list of awards won by the school.

Section 1.3 offered a foundation for this study starting with a discussion of the use of technology to support education. Particular attention was given to the online program FCAT Explorer, which provides mathematics practice problems for the 5th, 8th and 10th grade levels. Program design provides the unique feature of Correct Answer Explanation (CAE) in addition to hints to solve problems, opportunities to repeat questions answered incorrectly, and other features. This study was designed to evaluate the effectiveness of using FCAT Explorer in terms of students' perceptions of their learning environment and their attitudes towards mathematics.

Section 1.4 provides my research questions that focus on: the efficacy of the FCAT Explorer in terms of students' perceptions of their environments and attitudes towards mathematics; the validity of the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) and Test of Mathematics Related Attitudes (TOMRA); and associations between classroom environment and student attitudes towards mathematics. The research questions for this study were:

1. Are the TROFLEI and TOMRA valid when used in technology-supported middle-school mathematics classes?
2. Is the FCAT Explorer effective as a curriculum supplement for traditional mathematics instruction in terms of:
    a. students' perceptions of their classroom learning environment
    b. students' attitudes to mathematics?
3. Are there associations between students' perceptions of technology-supported classroom environments and their attitudes to mathematics?

The significance of this study was discussed in Section 1.5. My study provided evidence about the effectiveness of an internet-based mathematics software program. Another significant feature of this study was that it involved two separate administrations of the instruments rather than using a single administration of a questionnaire that allows students to respond to each question in terms of an actual and a preferred response. Lastly, this study made a contribution to the research in the learning environment field because it provided the first use of learning environment criteria to evaluate the internet-based software program FCAT Explorer.

5.2.2 Summary of Chapter 2 Devoted to Literature Review

Chapter 2 reviewed literature relevant to my study. Section 2.2 presented an overview of learning environments research from the point of view established in Fraser (1998a, 1998b) that student perceptions and reactions to their educational environment can contribute significantly to our understanding of educational processes. Starting with a review of Lewin (1936) and Murray (1938), past work that had formed the basis of learning environments research was presented, addressing how hospital, prison, university, and classroom environments were assessed using a steadily-growing number of instruments. But it was with the Learning Environment Inventory (LEI, Walberg, 1968) and the Classroom Environment Scale (CES, Moos, 1974) that the foundation for modern learning environment research in the United States was laid. Over the next quarter century, a variety of learning environment instruments came into existence, with 11 of these instruments described in Table 2.1. A review of each of these instruments was included leading up to a watershed in learning environment instruments, the What Is Happening In this Class? (WIHIC) designed by Fraser, Fisher and McRobbie (1996). The WIHIC consists of seven eight-item scales that, as a result of exhaustive validity testing in studies internationally, has strong credibility for the measurement of the psychosocial environment of classrooms.

Table 2.2 lists 22 studies that have used the WIHIC and their unique contributions to the learning environment field. This table identifies for each study the researcher(s), the country or countries in which the study was conducted, and the language(s) used in the study. Also included in the table are details about the sample size, grade level, and number of classrooms for each study. The table indicates that the WIHIC's factorial validity and reliability were established in all 22 studies. Table 2.2 also includes whether or not associations between student outcomes and the environment were investigated.

The robust nature of the WIHIC is significant for my research because the instrument that I used, the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI), incorporates the seven eight-item WIHIC scales as its core, thus bringing a rich, and well-validated tool to my study. Additionally, the WIHIC has been used in the evaluation of a variety of educational innovations, including inquiry-based laboratory activities, computer courses for working adults, and an innovative science course for prospective elementary teachers. In these and other evaluations mentioned in Section 2.2.3.3, the WIHIC and other learning environment instruments were able to measure the impact of innovations in terms of participant perceptions. The next section, 2.2.3.4, provided descriptions of research that had identified links between students' environment perceptions and their outcomes, showing with a high degree of recurrence that students' perceptions of their classroom environment exert influence on cognitive and affective outcomes.

Section 2.3 describes of the Test of Mathematics Related Attitudes (TOMRA), which is based upon the Test of Science Related Attitudes, has its roots in Klopfer's (1971) work, and assesses seven aspects of attitudes towards science and scientists. Studies involving both the TOMRA and TOSRA were reviewed in this section, showing that these instruments have been widely validated and used both internationally and in the United States.

Section 2.4 shifts to a brief overview of online mathematics support resources, as well as various legislative acts that led to the adoption of the Florida Comprehensive Assessment Test (FCAT). The development of a grading scale for schools and legislation that allowed students to change from a failing school to a high-performing school exerted performance pressure at the state, district and school site levels. One tool that was developed in an attempt to improve performance in mathematics, the FCAT Explorer, was discussed in terms of design commission, learner motivation criteria, and student interface. Figure 2.2 provides a flow chart of learner experiences when using the FCAT Explorer software.

Finally, Section 2.5 provided a historical overview of educational technology innovations, the focus of my study, and the results of 13 studies which all led to no apparent or appreciable differences. Table 2.3 provided these results which were then discussed in terms of the ongoing expenditures of large sums of money on programs and innovations that have little positive research support for their use.

5.2.3 Summary of Chapter 3 on Research Methods

Chapter 3 considered the research methods used in my study. Section 3.2 provided contextual information on the locale in which my study was conducted, starting with a discussion of Miami-Dade County's 340 schools and almost 350,000 students and then considering the ethnic composition of the district as a whole. Next, the school site for the study was discussed, including a description of its enrolment (1165 students), ethnic composition, unique characteristics (e.g. being an all-portable facility), and the method by which students were invited to participate in the research. Section 3.3 discussed the FCAT Explorer's place in the curriculum.

Section 3.4 discussed the instruments used in the quantitative portion of the study. The TROFLEI includes all seven eight-item scales from the WIHIC, along with the three additional scales of Differentiation, Computer Usage, and Young Adult Ethos to form the 80-item instrument. Also three modified eight-item scales from the TOMRA (Enjoyment of Mathematics, Normality of Mathematicians, and Attitude Toward Mathematical Inquiry) were included this study. The quantitative data collection involved two distinct administrations of the TROFLEI and the TOMRA, as pretests and a posttests, during a 10-week period when the FCAT Explorer was employed as the major component of mathematics instruction in all classes at the school site.

In addition to quantitative data collection, I undertook qualitative data collection. Student volunteers were sought, interviewed, and then asked to summarize the interviews in writing. Written responses, 144 in total, from 24 students were recorded word for word. Questions used in the interview were based on the five TROFLEI scales of Teacher Involvement, Investigation and Orientation to Task, Student Cohesiveness, Computer Usage, and Young Adult Ethos. A single question based on the TOMRA was included to allow students to describe the effect of using the FCAT Explorer on their attitudes towards mathematics. To present these findings, two methods were employed. The first was to present the responses in the form of a narrative that described visitors dropping into a classroom on a typical day; Section 4.5.1 presented this narrative. The second format used to present the qualitative data was to compile the responses into general ideas or topics in columnar format, ascertain emergent higher-order themes in a second column, and ultimately link these themes to the scales of the TROFLEI that were used in developing the third column.

5.3 Summary of Analyses and Findings in Chapter 4

A summary of the analyses and findings from Chapter 4 is presented below in four subsections. The first subsection discusses findings for my first research question involving the validity of the questionnaires (Section 5.3.1). The second subsection considers findings for the second set of research questions concerning the effectiveness of FCAT Explorer (Section 5.3.2). The third subsection addresses findings for the third question on attitude–environment associations (Section 5.3.3). Finally, findings emerging from the use of qualitative interviews are summarized in Section 5.3.4.

5.3.1 Findings for First Research Question Involving Validation of Questionnaires

Factor analysis of TROFLEI data, using the retention criteria that an item must have a loading of at least 0.40 with its own scale and less than 0.40 on all other scales, led to 14 items out of the 80 total items being removed. There were four items omitted from the Student Cohesiveness scale, five items from the Teacher Support scale, three items from the Involvement scale and one item from the Computer Usage scale. For the 66 items that remained, the proportion of the variance accounted for was 50.94% for the pretest and 57.14% for the posttest.

The factor structure of the 24 TOMRA scales was also tested by principal axis factoring with varimax rotation and Kaiser normalization. All 24 TOMRA items were retained. The proportion of the variance accounted for was 58.22% for the pretest and 65.32% for the posttest.

Internal consistency reliability was investigated using Cronbach alpha coefficient for each TROFLEI and TOMRA scale for two units of analysis (the student and the class mean) separately for the pretest and the posttest data. Reliability results for both the individual and the class mean unit of analysis indicated strong internal consistency reliability.

Overall, all 10 scales of the TROFLEI and all three TOMRA scales demonstrated satisfactory discriminant validity for the pretest and the posttest for two units of analysis (the student and the class mean).

ANOVA showed that each TROFLEI scale was able to distinguish between the learning environment perceptions of students in different classes when class membership was used as the independent variable.

5.3.2 Summary of Findings for Second Research Question Concerning Effectiveness of FCAT Explorer

Use of MANOVA showed that, during the 10-week period of time during which the FCAT Explorer was a central part of the students' curriculum, pretest–posttest differences were statistically significant for 8 of the 10 learning environment scales, while there were no statistically significant differences for the attitude scales. Students perceived a higher degree of Involvement, Investigation, Differentiation and Computer Usage, but a lower degree of Teacher Support, Task Orientation, Cooperation and Equity after using the FCAT Explorer. But effect size for pre–post differences were small for every scale. It was concluded that the FCAT Explorer offered neither a discernible advantage nor a disadvantage in terms of students' perceptions of their classroom environment and their attitudes towards mathematics.

5.3.3 Summary of Findings for Third Research Question Concerning Attitude–Environment Associations

Multiple regression analysis showed that Teacher Support was a significant independent predictor of Enjoyment with the student as the unit of analysis for both the pretest and the posttest, while Equity and Young Adult Ethos were significant independent predictors of Enjoyment for the class as the unit of analysis. As an independent predictor of Inquiry, Investigation was the learning environment scale that appeared for both the student and class as the units of analysis. The learning environment scale of Cooperation was an independent predictor of Normality for the pretest for both the student and class as the units of analysis.

5.3.4 Summary of Findings for Qualitative Data

Qualitative interview data were analysed in two ways, namely, a narrative and an emergent theme analysis. The narrative drew from 144 interview responses to create a snapshot of a typical middle-school mathematics classroom at the school at which my research was conducted. An emergent theme analysis allowed the derivation of 13 distinct emergent Ideas/Topics which were then linked to five TROFLEI scales and one attitude scale. Findings from these analyses supported the quantitative findings that more computer usage in mathematics led to less student enjoyment.

5.4 Limitations of the Study

As is true with all studies, there were limitations that were identified and addressed to the best of my ability. Every effort was made to ensure that the data used in this study were not subject to error or bias. The first limitation was associated with the size and ethnic composition of my sample. While all 1154 students were invited to participate, ultimately my sample size was 914 participants. Also, in a district with roughly 350,000 students, this sample represents only a relatively small percentage of the overall population. In terms of the representativeness of my sample, its ethnic composition and its proportion of urban and inner-city students mirrored the whole district to a large degree. However, despite these efforts, the somewhat limited sample size could have reduced the statistical power and the imperfect representativeness of the sample possibly could have reduced the generalizability of findings.

Another limitation is that, because my study was limited to only one middle school in a district that has over 60 middle schools, the ability to reach generalizable conclusions would be limited. If more resources were available, a larger, multi-school sample could have been drawn from a wider, more-diverse selection of schools.

Even though the questionnaire used in my study was convenient, economical, and written in language designed for school children, it is possible that some students could have misunderstood some items, misinterpreted the intention of some items, or provided distorted responses based upon their own expectations or what they thought that the researcher expected.

There were 49 different mathematics classes involved during this study and I was a teacher of 5 of those classes. It is therefore possible that, because I served in this dual role during the study, my participation could have potentially altered the results in some way.

Any study must focus on a limited number of criteria so as to minimize the number of variables. My study focused on the effectiveness of a particular mathematics software tool in terms of students' perceptions of their learning environment and attitudes. However, this focus excluded other potentially valuable criteria, especially student achievement.

Despite all students in the school being invited to participate in the study, not all students did. The reasons for this included parental permission being withheld, absence from school on the day when the pretest or posttest surveys were administered, or a lack of motivation to complete the survey. Still other students might not have made an honest effort to complete the survey seriously and might have provided random responses. Although a large percentage of students did complete the survey, the responses of 250 students were eliminated for the reasons mentioned above.

Although the statistical analysis methods used in this study were adequate for its purposes, there is always the potential to use even more rigorous and sophisticated analyses. For example, the relatively small sample size made it difficult to use the class mean as the unit of analysis or to conduct multilevel analysis. Also, when correlation and multiple regression analyses are used to investigate relationships between learning environment scales and student attitudinal outcomes, only linear relationships can be detected and non-linear relationship would be missed. The technique of confirmatory factor analysis could have been used to bolster my exploratory factor analysis.

Although qualitative methods contributed positively to my study in terms of providing richer insights, using only one qualitative data-collection method could have created limitations in terms of potential bias, off-task responses, and the influence of external variables. Additionally, even though this study relied upon 144 verbatim responses, the small sample size for interviews limits the generalizability of the findings.

Another limitation was that I was able to find only a small number of past studies related to FCAT Explorer during my literature review (see in Chapter 2). However, because none of the past studies included in the review employed learning environment criteria, my study was pioneering. To address this limitation, my study drew on the large and well-documented resources of learning environment research for a method of evaluating the effectiveness of a curriculum innovation in terms of students' perceptions of their classroom environments.

5.5 Recommendations for Future Research

The limitations discussed in Section 5.4 naturally lead to suggestions for future research. Future studies in this area could involve larger and more diverse samples that include students from a wider geographic area and multiple schools in order to increase the generalizability of results and the statistical power of analyses. Although this would necessitate coordinating data collection at multiple school sites, it would increase the scope of the sample especially in light of the huge ethnic, cultural and economic diversity that exists in a large urban school district.

The inclusion of student achievement data is the next suggestion for future research. Problems with timing of data collection because of school schedules, privacy rights, and arranging to follow students over a period of years to measure changes in achievement made it impractical to include achievement in my study.

Even though my study included valuable qualitative data-collection methods, the scope of this part of the research was limited. Therefore, future research might involve a larger sample size in attempt to extend the validity of the findings. Further, while my study used the personal interview method for qualitative data collection, other methods of interviewing and presenting qualitative data could be included. These alternatives could include focus groups, observations, and action research. The benefits of such mixed-methods are discussed by Tobin and Fraser (1998).

Another recommendation for future research would be to focus not on the physical trappings of the educational innovation, but rather the blended delivery of instruction. The practice of teaching would be considered in conjunction with the technological resource.

Future research with a larger sample size could employ more rigorous data-analysis methods than were used in my study. Multilevel analyses could be used with the teacher as the unit of analysis. Also confirmatory factor analysis could be used along with explanatory factor analysis. Finally, linear and non-linear relationships both could be investigated.

A last suggestion for future research is to make use of both actual and preferred forms of the TROFLEI. In contrast to my study that traced changed between pretest and posttest administrations of the TROFLEI, future research could focus on differences between actual and preferred classroom environment.

5.6 Implications and Contributions

The substantive contribution made by this research is that it is one of the first learning environment studies to investigate the efficacy of an online mathematics curriculum support tool.

A methodological contribution was that learning environment and attitude questionnaires were cross-validated and therefore made available to future researchers who wish to determine the efficacy of other curriculum tools. As a result of my study, researchers who wish to assess mathematics classroom environments and students' attitudes towards mathematics will have the benefit of validated, economical questionnaires to use among the middle-school population.

A practical implication of my study is that, while some scales showed a positive pre–post improvement, others showed a negative trend in terms of learning environment and attitude criteria. This suggests that caution should be applied before assuming that the newest piece of technology will lead to an improvement of students' perceptions of their learning environment and their attitude towards the subject of mathematics.

My tentative results for associations between environment and attitude scales have potential practical implications for the improvement of mathematics instruction for middle-school populations. For example, teacher support was the strongest predictor of enjoyment. However, during the 10-week period between the pretest and posttest administrations when the curriculum focused on the mathematics software, the results indicated that the students perceived a decrease in teacher support. Another example is that the qualitative data corroborated the quantitative findings in that the students viewed more computer usage in the context of mathematics in a negative light.

5.7 Final Comment

This is the first study of the effectiveness of an online mathematics resource tool, the FCAT Explorer, in terms of students' learning environment perceptions and attitudes towards mathematics. Additionally, this study provided additional validation data for the growing body of research involving the TROFLEI and a modified version of the TOMRA among middle-grades mathematics students in Miami-Dade County, Florida.

My study has implications for mathematics teachers who are looking for effective ways to incorporate technology, either in the form of hardware (such as student devices) or online software. My study suggests that learning environment instruments can provide important feedback about whether classroom environments are positive and effective. The conclusions reached in my study can be applied to the learning environments of mathematics classrooms, as well as to the learning environments of other subjects. This study contributes data regarding educational innovations and the methods that can be used to evaluate their impact on students.

Finally, in the rush to incorporate the latest gadget as the panacea for educational success, as Fraser (2001) suggests, this study along with many others show convincingly that paying more attention to the classroom environment is very likely to pay off in terms of student outcomes.

REFERENCES

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

Afari, E., Aldridge, J.M., Fraser, B.J., & Khine, M.S. (2013). Students' perceptions of the learning environment and attitudes in game-based mathematics classrooms. *Learning Environments Research, 13,* 131-150.

Aiken, L.R. (2002). *Attitudes and related psychosocial constructs: Theories, assessment, and research*. Thousand Oaks, CA: Sage Publications.

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

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

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

Aldridge, J.M., & Fraser, B.J. (2011). Effects and determinants of outcomes-focused learning environments, *Curriculum and Teaching*, *26*(1), 5-31.

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

Aldridge, J., Fraser, B., Fisher, D., Trinidad, S., & Wood, D. (2003, April). *Monitoring the success of an outcomes-based, technology-rich learning environment*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

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

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

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

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

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

Allport, G.W. (1935). Attitudes. In C. Murchison (Ed.), *Handbook of social psychology* (pp. 798-844). Worcester, MA: Clark University Press.

Anderson, G. (1998). *Fundamentals of educational research* (2nd ed.). Bristol, PA: Falmer Press.

Anderson, G.J., & Walberg, H.J. (1968). Classroom climate and group learning. *International Journal of Educational Sciences*, *2*, 175-189.

Ball, D.L., & Cohen, D.K. (1999). *Instruction, capacity, and improvement* (CPRE Research Report No. RR-43). Philadelphia, PA: University of Pennsylvania, Consortium for Policy Research in Education.

Barmby, P., Kind, P.M., & Jones, K. (2008). Examining changing attitudes in secondary school science. *International Journal of Science Education, 30,* 1075-1093.

Beard, M.H., Lorton, P.V., Searle, B.W., & Atkinson, T.C. (1973). *Comparison of student performance and attitude under three lesson-selection strategies in computer-assisted instruction*. Stanford, CA: Defense Technical Information Center.

Bell, B., Jones A., & Carr, M. (1995) The development of the recent national New Zealand science curriculum. *Studies in Science Education, 26*, 73-105.

Bolliger, D.U., & Martindale, T. (2004). Key factors in determining student satisfaction in online courses. *International Journal on E-Learning, 31*(1), 61-67.

Botha, R.J. (2002). Outcomes-based education and educational reform in South Africa. *International Journal of Leadership in Education, 5,* 361-371.

Brekelmans, M., Wubbels, Th., & van Tartwijk, J. (2005). Teacher–student relationships across the teaching career. *International Journal of Educational Research, 43*, 55-71.

Brutus, S. et al. (2013). Self-reported limitations and future directions in scholarly reports: Analysis and recommendations. *Journal of Management, 39*, 48-75, (January, 2013).

Campbell, D.T., & Fiske, D.W. (1959). Convergent and discriminant validation by multitrait multimethod matrix. *Psychological Bulletin*, *56*, 81-105.

Carnegie Forum on Education and the Economy. (1986). *A nation prepared: Teachers for the 21st century*. New York: Author.

Castillo, G.E., Peiro, M.M., & Fraser, B.J. (2005, August). *Grade-level, gender and ethnic differences in attitudes and learning environment in high school mathematics*. Paper presented at the Fourth International Conference on Science, Mathematics, and Technology Education, Victoria, BC, Canada.

Cavalluzzo, L.C. (2004, November). *Is National Board Certification an effective signal of teacher quality?* Paper presented at the Consortium for Policy Research in Education's National Conference on Teacher Compensation and Evaluation, Chicago, IL.

Cennamo, K.S. (1990). *Can interactive video overcome the "couch potato" syndrome?* Paper presented at the Convention of the Association for Educational Communications and Technology, Anaheim, CA.

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

Clandinin, D. J., & Connelly, F.M. (1994). Personal experience method. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 413-427). Newbury Park, CA: Sage.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). New York: Academic Press.

Creswell, J., & Plano Clark, V. (2007). *Designing and conducting mixed method research.* Thousand Oaks, CA: Sage Publications.

Créton, H., & Wubbels, Th. (1984) *Ordeproblem bij beginnende leararen* [Discipline problems of beginning teachers]. Utrecht, The Netherlands: W.C.C.

Cunningham, G.K., & Stone, J.E. (2005). Value-added assessment of teacher quality as an alternative to the National Board for Professional Teaching Standards: What recent studies say. In R. Lissitz (Ed.), *Value added models in education: Theory and applications* **(**pp. 209-232). Maple Grove, MN: JAM Press.

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

Denzin, N.K. (1978). *The research act: A theoretical introduction to sociological methods*. New York: MacGraw-Hill.

Denzin, N, & Lincoln, Y. (2008). *Collecting and interpreting qualitative materials* (3rd ed.). Thousand Oaks, CA: Sage Publications Inc.

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

Dhindsa, H.S., & Fraser, B.J. (2011). Culturally sensitive factors in the learning environment of science classrooms in Brunei Darussalam. *The Open Education Journal, 4,* 90–99.

Dick, W., & Carey, J.O. (1996). *The systematic design of instruction* (4th ed.) New York: Harper Collins.

Dorman, J.P. (2001). Associations between classroom environment and academic efficacy. *Learning Environments Research, 4,* 243-257.

Dorman, J.P. (2002). Classroom environment research: Progress and possibilities. *Queensland Journal of Educational Research*, *18* (12), 112-140.

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

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

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

Dryden, M., & Fraser, B.J. (1998, April). *The impact of systemic reform efforts in promoting constructivist approaches in high school science.* Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA,

Eagly, A.H., & Chaiken, S. (1993). *The psychology of attitudes*. Fort Worth, TX; Harcourt Brace Jovanovich.

Education Commission of the States. (1995). *"Outcomes-based" education: An overview.* Denver, CO: Author.

Erickson, F. (2012). Qualitative research methods for science education. In B. J. Fraser, K. G. Tobin and C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 1451–1469). New York: Springer.

Evans, K.M., & King, J.A. (1994). Research on OBE: What we know and don't know. *Educational Leadership, 51*(6), 12-17.

Fahy, P.J. (2000). *Achieving quality with online teaching technologies.* Paper presented at Quality Learning 2000 Inaugural International Symposium, Calgary, AB. (ERIC document Reproduction Service No. ED445197)

Faris, R. (1998). *From elitism to inclusive education: Development of outcomes-based learning and post-secondary credit accumulation and transfer systems in England and Wales.* Victoria, BC: Centre for Curriculum, Transfer and Technology.

Fennema, E., & Sherman, J.A. (1976). Fennema-Sherman mathematics attitudes scales, instruments designed to measure attitudes towards the learning of mathematics by females and males. *Catalog of Selected Documents in Psychology*, *6*(1), 31.

Finn, C.E., & Wilcox, D.D. (1999). *Board games: Failure of the National Board for Professional Teaching Standards to accomplish objective of improving quality of teaching in the US: Business backs a losing strategy.* Retrieved January 1, 2006 from. http://www.edexcellence.net/foundation/publication/publication.cfm?id=161

Finn, C.E., & Wilcox, D.D. (2000). *Teachers should be graded on how well their students are learning.* Retrieved January 1, 2006 from http://www.edexcellence.net/foundation/publication/publication.cfm?id=102

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

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

Fisher, D.L., & Fraser, B.J. (1992). Validity and use of school environment instruments. *Journal of Classroom Interaction, 26*(2), 13-18.

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

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

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

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

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

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

Fisher, D.L., & Waldrip, B.G. (1999). Cultural factors of science classroom learning environments, teacher–student interactions and student outcomes. *Research in Science and Technological Education*, *17*, 83–96.

Fletcher, G.H. (2010). Race to the top: No district left behind. *T. H. E. Journal, 37*(10), 17-18.

Florida Department of Education. (2004). *FCAT Florida Comprehensive Assessment Test.* Retrieved February 19, 2013, from: http://fcat.fldoe.org/pdf/fcataabb.pdf.

Florida Department of Education. (2005). *FCAT 2.0 background.* Retrieved March 18, 2009, from http://fcat.fldoe.org/handbk/background.pdf.

Folleck, J. (2005). *Education audit criticizes FCAT contract award.* Ocala Star Banner, July 2. Retrieved from: http://news.google.com/newspapers? nid=hXZnTIgIr50C& dat=20050702&b_mode=2&hl=en, March 16, 2010.

Fraser, B.J. (1979). Evaluation of a science-based curriculum. ln H.J. Walberg (Ed.), *Educational environments and effects: Evaluation, policy, and productivity* (pp. 218-234). Berkeley, CA.: McCutchan.

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

Fraser, B.J. (1981b). Using environmental assessments to make better classrooms. *Journal of Curriculum Studies*, *13*, 131-144.

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

Fraser, B.J. (1989). *Assessing and improving classroom environment* (What Research Says, No. 2). Perth, Australia: Curtin University of Technology.

Fraser, B.J. (1991). Two decades of classroom learning environment research. In B.J. Fraser & H.J. Walberg (Eds.), *Educational environments: Evaluation, antecedents and consequences* (pp. 3-27). London, England: Pergamon Press.

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. (1996, March). *NARST's expansion, internationalization, and cross nationalization: History in the making.* Presidential address at the annual meeting of the National Association for Research in Science Teaching, St Louis, MO.

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

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

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

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

Fraser, B.J. (2012). Classroom learning environments: Retrospect, context and prospect. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 1191–1239). New York: Springer.

Fraser, B.J. (2014). Classroom learning environments: Historical and contemporary perspectives. In N.G Lederman & S. K. Abell (Eds.), *Handbook of research on science education*. Volume II (pp. 104-117). New York: Routledge.

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

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

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

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

Fraser, B.J., Dryden, M., & Taylor, P. (1998, April). *The impact of systemic reform efforts on instruction in high school science classes*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Diego, CA.

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

Fraser, B.J., & Fisher, D.L. (1986). Using short forms of classroom climate instruments to assess and improve classroom psychosocial environment. *Journal of Research in Science Teaching*, *23*, 387-413.

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

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

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

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

Fraser, B.J., & McRobbie, C.J. (1995). Science laboratory classroom environments at school and universities: A cross-national study. *Educational Research and Evaluation, 1*, 289-317.

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

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

Fraser, B.J., & Raaflaub, C. (2013). Subject and sex differences in the learning environment – Perceptions and attitudes of Canadian mathematics and science students using laptop computers. *Curriculum & Teaching 28* (1): 57-58.

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

Fraser, B.J., & Treagust, D.F. (1986). Validity and 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*. Oxford, England: Pergamon Press.

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

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

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

Gay, L.R., & Airasian, P. (Eds.). (1996). *Educational research: Competencies for analysis and application* (6th ed.). Upper Saddle River, NJ: Merrill Publishing Company.

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

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

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

Goldberg, F. (1997). *Constructing physics understanding in a computer-supported learning environment*. San Diego: The Learning Team.

Goldenberg, E.P., & Cuoco, A. (1996). What is dynamic geometry? In R. Lehler & D. Chazan (Eds.), *Designing learning environments for developing understanding of geometry and space* (pp. 381-420). Hillsdale, NJ: Erlbaum.

Goldhaber, D., & Anthony, E. (2004). *National Board Certification: Who applies and what factors are associated with success?* The Urban Institute, Education Policy Center. [On-line], Available: http://www.urban.org/EmilyAnthony

Greene, J., & Caracelli, V. (1997). *Advances in mixed-method evaluation: The challenges and benefits of integrating diverse paradigms* (New Directions for Evaluation). San Francisco: Jossey-Bass.

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

Hawkes, M., & Dennis, T. (2003). Supporting and assessing online interactions in higher education. *Educational Technology, 43*(4), 52-56.

Hawkins, J. (1993). Technology and the organization of schooling. *Communications of the ACM, 36*(5), 30-34.

Helding, K.A., & Fraser, B.J. (2013). Effectiveness of National Board Certification (NBC) teachers in terms of classroom environment, attitudes and achievement among secondary science students. *Learning Environments Research, 13,* 1-21.

Henderson, D. G., Fisher, D. L. & Fraser, B. J. (1998). Learning environment and student attitudes in environmental science classrooms. *Proceedings Western Australian Institute for Educational Research Forum 1998*.

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

Hirata, S., & Sako, T. (1998). Perceptions of school environment among Japanese junior high school, non-attendant, and juvenile delinquent students. *Learning Environments Research, 1*, 321-331.

Hopkins, C. (2002). *Toronto Board of Education curriculum revision and reorientation* [On-line]. Retrieved from www.estoolkit.org.

Huang, T.-C.I., Aldridge, J.M., & Fraser, B.J. (1998). A collaborative study of science classroom environments between Taiwan and Australia: Combining qualitative and quantitative research methods. *Chinese Journal Science Education, 6*, 343-362.

Kanner, J.H., Runyon, R.P., & Desiderato, O. (1954). *Television in army training: Evaluation of television in army basic training*. Washington, DC: George Washington University.

Keller, B. (2005). Panel urges new testing for teachers. *Education Week*, *24*(38), 1-16.

Keller, J.M. (1987). Development and use of the ARCS model of instructional design. *Journal of Instructional Development, 10*(3), 2-10.

Kerka, S. (1998). *Competency-based education and training: Myths and realities* [On-line. Retrieved from ERIC.ed.gov (ED415430).

Khine, M.S. (1996). The interaction of cognitive styles with varying levels of feedback in multimedia presentation. *International Journal of Instructional Media, 23*, 229-237.

Khine, M.S., & Fisher, D.L. (2004). Teacher interaction in psychosocial learning environment: Cultural differences and their implications for science teaching. *Research in Science and Technological Education, 22*, 99-11.

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

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

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

Kim, J.K., & Sharp, J.M. (2000). Investigating and measuring preservice elementary mathematics teachers' decision about lesson planning after experiencing technologically-enhanced methods instruction. *The Journal of Computers in Mathematics and Science Teaching, 19*, 317-338.

Kind, P.K., & Barmby, P. (2011). Defending attitude scales. In I. M. Saleh and M. S. Khine (Eds.), *Attitude research in science education: Classic and contemporary measurements* (pp. 117–135). Charlotte, NC: Information Age Publishing.

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

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

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

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

Kvale, S. (1996). *InterViews: An introduction to qualitative research interviewing.* Thousand Oaks, CA: Sage.

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

Lee, S.S.U. (2001). *Assessment, description and effects of science classroom environments in Korea.* Unpublished doctoral dissertation, Curtin University of Technology, Perth, Australia.

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

Leitch, R. (1993, July) *The implications of intra-psychic reflection on the professional and moral development of teachers*. Paper presented at University of Exeter Conference on Moral and Spiritual Development, RIMSCUE Centre, Exeter, United Kingdom.

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

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

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. London: Sage Publications.

Loder, J.E. (1937). *A study of aural learning with and without the speaker present*. Lincoln, NE: University of Nebraska.

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

Lucas, K.B., & Roth, W.M. (1996). The nature of scientific knowledge and student learning: Two longitudinal case studies. *Research in Science Education, 26*, 103-129.

Lucas, K.B., & Tulip, D.F. (1980, September). *Scientific literacy of high school students*. Paper presented at the annual conference of the Australian Science Teachers Association, Canberra.

MacDowell-Goggin, M. (2005). *Effect of using graphic organizers on the attitudes and classroom environment of elementary science students*. Unpublished doctoral thesis, Curtin University of Technology.

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

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

Maor, D. (1999). Teachers as learners: The role of a multimedia professional development program in changing classroom practice. *Australian Science Teachers Journal, 45* (3), 49-50.

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., Aldridge, J.M., & Fraser, B.J. (2004). Learning environment perceptions, attitudes and achievement among private Indonesian university students. *International Journal of Private Higher Education.* Retrieved January 18, 2005, from http://www.xaiu.com/xaiujournal/

Martindale, T., Pearson, C., Curda, L.K., & Pilcher, J. (2005) Effects of an online instructional application on reading and mathematics standardized test scores. *Journal of Research on Technology in Education*, *37*, 349-360.

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

Mathison, S. (1988). Why triangulate? *Educational Researcher*, *17*, 13-17.

McDonald, K.K., & Hannafin, R.D. (2003). Using web-based computer games to meet the demands of today's high-stakes testing: A mixed method inquiry. *Journal of Research on Technology in Education, 35*, 459-472.

McGuire, W.J. (1968). The nature of attitudes and attitude change. In G. Lindzey & E. Aronson (Eds.), *Handbook of social psychology* (3nd ed., Vol. 2, pp. 233-246) New York: Random House.

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

Miami-Dade County Public Schools. (2003). *Miami-Dade County Public Schools student progression plan 2003-2004.* Retrieved July 1, 2005, from http://www.dadeschools.net/ehandbook/student03/Section%20I/2003%20General%20Procedures%20for%20Student%20Progression,%20K%20-%201.pdf

Miami-Dade County Public Schools. (2004). *District demographic*. Retrieved July 1, 2005, from Miami-Dade County Public Schools Web site: http://oada.dadeschools.net/04Profiles.htm

Milne, C. & Taylor, P.C. (1996, April). *School science: A fertile culture for the evolution of myths*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, St Louis, MO.

Mink, D.V., & Fraser, B.J. (2005). Evaluation of a K–5 mathematics program which integrates children's literature: Classroom environment and attitudes. *International Journal of Science and Mathematics Education*, *3*, 59-85.

Mock, R. (2000). *Comparison of online coursework to traditional instruction.* Unpublished thesis, Michigan State University, East Lansing, MI.

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. (1974). *Classroom Environment Scale manual*. Palo Alto, CA: Consulting Psychologists Press.

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

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.

Moss, G., Jewitt, C., Levaaic, R., Armstrong, V., Cardini, A., & Castle, F. (2007). *Interactive whiteboards, pedagogy, and pupil performance: An evaluation of the schools whiteboard expansion project (London Challenge)*. London: Department for Education and Skills/Institute of Education, University of London.

Munby, H. (1983). *An investigation into the measurement of attitudes in science education.* Columbus, OH: Ohio State University. ERIC Document #ED 237347.

Munby, H. (1997). Issues of validity in science attitude measurement. *Journal of Research in Science Teaching, 34*, 337–341.

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

Naime-Diefenbach, B. (1991). *Validation of attention and confidence as independent components of the ARCS motivational model.* Unpublished doctoral dissertation. Florida State University, Tallahassee.

Naime-Diefenbach, B., & Sullivan, C.B. (2001) *Measuring the effects of a web-based practice program on the FCAT math results of fifth graders*. Paper presented at the Florida Educational Research Association Annual Conference, Marco Island, FL.

Naime-Diefenbach, B., & Sullivan, C.B. (2003, November) *Using the FCAT Explorer to improve 5th graders' math FCAT performance.* Paper presented at the Florida Educational Research Association Annual Conference, Orlando, FL.

National Board for Professional Teaching Standards. (2000). *A distinction that matters: Why national teacher certification makes a difference.* Retrieved February 8, 2003, from http://www.mprinc.com/pubs/pdf/ distinction_that_matters.pdf

National Board for Professional Teaching Standards. (2001). *I am a better teacher: What candidates for National Board Certification say about the assessment process.* Retrieved February 8, 2003, from http://www.nbpts.org/pdf/better_teacher.pdf

Newby, M., & Fisher, D.L. (1997) An instrument for assessing the learning environment of a computer laboratory. *Journal of Educational Computing Research, 16*, 179-197.

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

No Child Left Behind (NCLB) Act of 2001, Pub. L. No. 107-110, § 115, Stat. 1425 (2002).

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

Ortega, J. (2001). *The FCAT Explorer: The Florida Department of Education's new practice programs*. FETConnections, Florida Educational Technology Corporation, Inc., Winter, 2001. Retrieved, October 10, 2006 from: HYPERLINK "http://www.fetc.org/fetcon/2001-Fall/fcat_explorer.htm" http://www.fetc.org/fetcon/2001-Fall/fcat_explorer.htm.

Osborne, J., Simons, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implication. *International Journal of Science Education, 25,* 1049–1079.

Oser, R. (2013) *Effectiveness of virtual laboratories in terms of achievement, attitudes and learning environment among high school science students.* Unpublished PhD thesis, Curtin University.

Partin, G.R., & Atkins, E.L. (1984). Teaching via the electronic blackboard. In L. Parker & C. Olgren (Eds.), *Teleconferencing and electronic communication III* **(**pp. 68-73). Madison, WI: University of Wisconsin Extension, Center for Interactive Programs.

Patton, M. (2002). *Qualitative research and evaluation method* (3rd ed.). Thousand Oaks, CA: Sage Publications.

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

Pickett, L.H., & Fraser, B.J. (2009). Evaluation of a mentoring program for beginning teachers in terms of the learning environment and student outcomes in participants' school classrooms. In A. Selkirk and M. Tichenor (Eds.), *Teacher education: Policy, practice and research* (pp. 1-15): New York: Nova.

Pickett, L., & Fraser, B.J. (2010). Creating and assessing positive learning environments. *Childhood Education, 86*, 321-326.

Podgursky, M. (2001a). Defrocking the National Board. *Education Next, 1* (2), 79-82.

Podgursky, M. (2001b). *Should state subsidize National Certification*? Retrieved February 11, 2003, from www.edweek.org

Punch, K.F. (1998). *Introduction to social research*. London, England: Sage Publications.

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

Quek, C.L., Wong, A.F.L., & Fraser, B. (2005b). Teacher–student interaction and gifted students' attitudes toward chemistry in laboratory classrooms in Singapore. *Journal of Classroom Interaction, 40*(1), 18-28.

Raaflaub, C., & Fraser, B.J. (2013). Subject and sex differences in the learning environment-perceptions and attitudes of Canadian mathematics and scienc students using laptop computers. *Curriculum and Teaching 28*(1), 57-78.

Rentoul, A.J., & Fraser B.J. (1979). Conceptualization of inquiry-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.

Richards, L., & Morse, J.M. (2007). *Users guide for qualitative methods* (2^{nd} ed.). Thousand Oaks, CA: Sage.

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

Roth, W.M., & Bowen, G.M. (1995). Knowing and interacting: A study of culture, practices, and resources in a grade 8 open-inquiry science classroom guided by a cognitive apprenticeship metaphor. *Cognition and Instruction, 13*, 73-128.

Roth, W.M., & Roychoudhury, A. (1993). The nature of scientific knowledge, knowing and learning: The perspectives of four physics students. *International Journal of Science Education, 15*, 27-44.

Rulon, P.V. (1943). A comparison of phonographic recordings with printed motivation to further study. *The Harvard Educational Review, 8*, 246-255.

Russell, T.L. (1999). *The no significant difference phenomenon*. Raleigh, NC: North Carolina State University.

Saettler, L.P. (2004). *The evolution of American educational technology*. Charlotte, NC: Information Age Publishing, Inc.

Saleh, I.M., & Khine, M.S. (Eds.). (2011). *Attitude research in science education: Classic and contemporary measurements.* Charlotte, NC: Information Age Publishing.

Sanders, W.B. (2001). *Creating learning-centered courses for the world wide web.* Boston & London: Allyn and Bacon.

Sandman, R.S. (1980). The mathematics attitude inventory: Instrument and user's manual. *Journal for Research in Mathematics Education, 11*, 148-149.

Schank, R.C. (1993). Learning via multimedia computers. *Communications of the ACM, 36*(1), 54-56.

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

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

Schoenfeld, A. (1992). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. In D.A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 334-370). New York: Macmillan.

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

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

Seibert, W.F., & Honig, J.M. (1960). A brief study of televised laboratory instruction. *Educational Technology Research and Development, 8*, 115-123.

Shulman, L.S. (1997). Disciplines of inquiry in education: A new overview. In R.M. Jaeger (Ed.), *Complementary methods for research in education* (2nd ed., pp. 3-29). Washington, DC: American Educational Research Association.

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. (2003). Changing classroom environments in urban middle schools. *Learning Environments Research: An International Journal*, *5*, 201-328.

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

Soto-Rodriguez, M., & Fraser, B.J. (2004, April). *A comparison of attitudes, achievement, and classroom environment perceptions of LEP (Limited English Proficient) and non-LEP students in integrated science classrooms*. Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Spady, W. (1994). *Outcomes-based education: Critical issues and answers*. Arlington, VA: American Association of School Administrators,.

Spady, W. (1998). *Paradigm lost: Reclaiming America's education future*. Arlington, VA: American Association of School Administrators.

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

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

Stone, J.E. (2002, May). *Value-added achievement gains of NBPTS-certified teachers in Tennessee: A brief report.* Retrieved July 21, 2005, from www.education-consumers.com/briefs/may2002.asp

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

Taylor, P.C. (1996). Mythmaking and mythbreaking in the mathematics classroom. *Educational Studies in Mathematics, 31,* 151-173.

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

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

Teddie, C., & Tashakkori, A. (2009). *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Thousand Oaks, CA: Sage Publications.

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

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

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

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

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

Tytler, R., & Osborne, J. (2012). Student attitudes and aspirations towards science. In B. J. Fraser, K. G. Tobin and C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 597–625). New York: Springer.

U.S. Census Bureau. (2000). *Florida quick facts*. Retrieved June 25, 2005, from http://quickfacts.census.gov/qfd/states/12000.html

U.S. Department of Education. (1983). *A nation at risk: The imperative for education reform* (Publication No. 065-000-00177-2). Washington, DC: Author. Retrieved August 20, 2004 from: http://www.ed.gov/pubs/NatAtRisk/risk.html

U.S. Department of Education. (2010a). *Carnegie learning curricula and cognitive tutor software.* Washington, DC: What Works Clearinghouse.

U.S. Department of Education. (2010b). *Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies.* Retrieved October 22 2013 from: http://www2.ed.gov/rschstat/eval/techevidence-based-practices /finalreport.pdf.

Van der Meer, A.W. (1950). *Relative effectiveness of instruction by films exclusively, films plus study guides, and standard lecture methods*. (Technical Report No. SDC 269-7-130). Port Washington, NY: U.S. Navy Training Devices Center.

Vandevoort, L.G., Amrein-Beardsley, A., & Berliner, D.C. (2004). National Board Certified teachers and their students' achievement. *Education Policy Analysis Archives*. Retrieved January 20, 2005 from: http://epaa.asu.edu/epaa/v12n46/

Verzoni, K.A. (1997). Turning students into problem solvers. *Mathematics Teaching in the Middle School*, *3*, 102-107.

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

Walberg, H.J. (1968). Teacher personality and classroom climate. *Psychology in the Schools*, *5*, 163-169.

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

Walberg, H.J. (1984**).** Improving the productivity of America's schools. *Educational Leadership*, *41*, 19-27.

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

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

Walberg, H.J., Fraser, B.J., & Welch, W.W. (1986). A test of a model of educational productivity among senior high school students. *Journal of Educational Research, 39*, 133-139.

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

Watzlawick, P., & Beavin, J. (1967). Some formal aspects of communication. *ABI/INFORM Global, 10*(8), 4-8.

Weisberg, M. (2011). Student attitudes and behaviors towards digital textbooks. *Publishing Research Quarterly, 27*, 188-196.

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

Wilcox, D.D. (2003). *The National Board for Professional Teaching Standards: Can it live up to its promise*? Retrieved February 11, 2003, from http://www.edexcellence.net/better/tchrs/13.htm

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

Woelfel, N., & Tyler, I. K. (1945). *Radio and the school*. Tarrytown, NY: World Books.

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

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

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

Wright, V., Barron, A.E., & Kromrey, J.D. (1999). Preparing students for high-stakes testing in Florida: An interactive website. *Florida Journal of Educational Research, 39*(1), 79-94.

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

Wubbels, Th., & Brekelmans, M. (2012). Teacher–students relationships in the classroom. In B.J. Fraser, K.G. Tobin & C.J. McRobbie (Eds.), *Second international handbook of science education* (pp. 1241-1255). New York: Springer.

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

Wubbels, Th., Créton, H.A., & Hooymayers, H.P. (1985, March-April). *Discipline problems of beginning teachers: Interactional teacher behaviour mapped out*. Paper presented at Annual Meeting of the American Education Research Association, Chicago.

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

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

Zandvliet, D. (2003, April). *Learning environments in Malaysian "Smart School" classrooms*. Paper presented at the annual meeting of the American Educational Research Association, Chicago.

Zandvliet, D.B. (2012). Development and validation of the Place-based Learning And Constructivist Environment Survey (PLACES). *Learning Environments Research, 15,* 125-140.

Zandvliet, D.B. (2013). Developing SMILES: Evaluating place-based learning. In D. Zandvliet (Ed.), *The ecology of school* (pp. 105-119). Rotterdam: Sense.

Zandvliet, D.B., & Fraser, B.J. (2004). Learning environments in information and communication technology classrooms. *Technology, Pedagogy and Education*, *13*(1), 97-123.

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

Every reasonable effort has been made to acknowledge the owners of copyright material. I would be pleased to hear from any copyright owner who has been omitted or incorrectly acknowledged.

APPENDIX A

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

Test of Mathematics Related Attitudes (TOMRA)

Items 1–80 in this questionnaire are from the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI, Aldridge & Fraser, 2008) and Items 81–104 are based on items selected from the Test of Science Related Attitudes (TOSRA, Fraser, 1981a). These questionnaire scales and items were used in my study and included in this thesis with the permission of their authors.

This survey is used to measure how you feel about your mathematics class. By using the following scale, answer how you feel today regarding these items on the answer sheet provided:

I **almost never** feel this way in math class.
I **seldom** feel this way in math class.
I **sometimes** feel this way in math class.
I **often** feel this way in math class.
I **very often** feel this way in math class.

SC		Almost Never	Seldom	Some times	Often	Almost Always
1	I make friends among students in this class.	1	2	3	4	5
2	I know other students in this class.	1	2	3	4	5
3	I am friendly to members of this class.	1	2	3	4	5
4	Members of the class are my friends.	1	2	3	4	5
5	I work well with other class members.	1	2	3	4	5
6	I help other class members who are having trouble with their work.	1	2	3	4	5
7	Students in this class like me.	1	2	3	4	5
8	In this class, I get help from other students.	1	2	3	4	5
TS		Almost Never	Seldom	Some times	Often	Almost Always
9	The teacher takes a personal interest in me.	1	2	3	4	5
10	The teacher goes out of his/her way to help me.	1	2	3	4	5
11	The teacher considers my feelings.	1	2	3	4	5
12	The teacher helps me when I have trouble with my work.	1	2	3	4	5
13	The teacher talks with me.	1	2	3	4	5
14	The teacher is interested in my problems.	1	2	3	4	5
15	The teacher moves about the class to talk with me.	1	2	3	4	5
16	The teacher's questions help me to understand.	1	2	3	4	5

Inv	Almost Never	Seldom	Some times	Often	Almost Always
17 I discuss ideas in this class.	1	2	3	4	5
18 I give my opinions during class discussions.	1	2	3	4	5
19 The teacher asks me questions.	1	2	3	4	5
20 My ideas and suggestions are used during classroom discussions.	1	2	3	4	5
21 I ask the teacher questions.	1	2	3	4	5
22 I explain my ideas to other students.	1	2	3	4	5
23 Students discuss with me how to go about solving problems.	1	2	3	4	5
24 I am asked to explain how I solve problems.	1	2	3	4	5
Invs	Almost Never	Seldom	Some times	Often	Almost Always
25 I carry out investigations to test my ideas.	1	2	3	4	5
26 I am asked to think about the evidence for my statements.	1	2	3	4	5
27 I carry out investigations to answer questions coming from discussions.	1	2	3	4	5
28 I explain the meaning of statements, diagrams, and graphs.	1	2	3	4	5
29 I carry out investigations to answer questions that puzzle me.	1	2	3	4	5
30 I carry out answers to questions by doing investigations.	1	2	3	4	5
31 I find out answers to questions by doing investigations.	1	2	3	4	5
32 I solve problems by using information obtained from my own investigations.	1	2	3	4	5

TO		Almost Never	Seldom	Some times	Often	Almost Always
33	Getting a certain amount of work done is important to me.	1	2	3	4	5
34	I do as much as I set out to do.	1	2	3	4	5
35	I know the goals for this class.	1	2	3	4	5
36	I am ready to start class on time.	1	2	3	4	5
37	I know what I am trying to accomplish in this class.	1	2	3	4	5
38	I pay attention during this class.	1	2	3	4	5
39	I try to understand the work in this class.	1	2	3	4	5
40	I know how much work I have to do.	1	2	3	4	5
CO		Almost Never	Seldom	Some times	Often	Almost Always
41	I cooperate with other students when doing assignment work.	1	2	3	4	5
42	I share my books and resources with other students when doing assignments.	1	2	3	4	5
43	When I work in groups in this class, there is teamwork.	1	2	3	4	5
44	I work with other students on projects in this class.	1	2	3	4	5
45	I learn from other students in this class.	1	2	3	4	5
46	I work with other students in this class.	1	2	3	4	5
47	I cooperate with other students on class activities.	1	2	3	4	5
48	Students work with me to achieve class goals.	1	2	3	4	5

Eq		Almost Never	Seldom	Some times	Often	Almost Always
49	The teacher gives as much attention to my questions as to other students' questions.	1	2	3	4	5
50	I get the same amount of help from the teacher as do other students.	1	2	3	4	5
51	I have the same amount of say in this class as other students do.	1	2	3	4	5
52	I am treated the same as other students in this class.	1	2	3	4	5
53	I receive the same encouragement from the teacher as other students do.	1	2	3	4	5
54	I get the same opportunity to contribute to class discussions as other students.	1	2	3	4	5
55	My work receives as much praise as other students' work.	1	2	3	4	5
56	I get the same opportunity to answer questions as other students.	1	2	3	4	5
Dif		**Almost Never**	**Seldom**	**Some times**	**Often**	**Almost Always**
57	I work at my own speed.	1	2	3	4	5
58	Students who work faster than me move on to the next topic.	1	2	3	4	5
59	I am given a choice of topics.	1	2	3	4	5
60	I am set tasks that are different from other students' tasks.	1	2	3	4	5
61	I am given work that suits my ability.	1	2	3	4	5
62	I use different materials from those used by other students.	1	2	3	4	5
63	I use different assessment methods from other students.	1	2	3	4	5
64	I do work that is different from other students' work.	1	2	3	4	5

CU	Almost Never	Seldom	Some times	Often	Almost Always
65 I use the computer to type my assignments.	1	2	3	4	5
66 I use the computer to email assignments to my teacher.	1	2	3	4	5
67 I use the computer to ask the teacher questions.	1	2	3	4	5
68 I use the computer to find out information about the course.	1	2	3	4	5
69 I use the computer to read lesson notes prepared by the teacher.	1	2	3	4	5
70 I use the computer to find out information about how my work will be assessed.	1	2	3	4	5
71 I use the computer to take part in online discussions with other students.	1	2	3	4	5
72 I use the computer to obtain information from the Internet.	1	2	3	4	5
YA	Almost Never	Seldom	Some times	Often	Almost Always
73 I am treated like a young adult.	1	2	3	4	5
74 I am given responsibility	1	2	3	4	5
75 I am expected to think for myself.	1	2	3	4	5
76 I am dealt with as a grown up.	1	2	3	4	5
77 I am regarded as reliable.	1	2	3	4	5
78 I am considered mature.	1	2	3	4	5
79 I am given the opportunity to be independent.	1	2	3	4	5
80 I am encouraged to take control of my own learning.	1	2	3	4	5

En Mth		Almost Never	Seldom	Some times	Often	Almost Always
81	Mathematics lessons are fun.	1	2	3	4	5
82	School should have more math lessons each week.	1	2	3	4	5
83	Mathematics is one of the most interesting school subjects.	1	2	3	4	5
84	I really enjoy going to mathematics lessons.	1	2	3	4	5
85	I look forward to math lessons.	1	2	3	4	5
86	I like math lessons.	1	2	3	4	5
87	The material covered in math lessons is interesting.	1	2	3	4	5
88	I would enjoy school more if there were more math lessons.	1	2	3	4	5
Mth Enq		Almost Never	Seldom	Some times	Often	Almost Always
89	I would prefer to find out why something is true by doing a problem than by being told.	1	2	3	4	5
90	I would prefer to do problems than read about them.	1	2	3	4	5
91	I would prefer to do my own problems than have a teacher explain them.	1	2	3	4	5
92	I would rather solve a problem by experimenting than be told the answer.	1	2	3	4	5
93	I would prefer to do a problem on a topic than to read about it in a textbook.	1	2	3	4	5
94	I would rather find things by working on my own than by asking an expert than.	1	2	3	4	5
95	It is better to find out by trying a problem than to ask the teacher the answer.	1	2	3	4	5
96	It is better to find mathematical facts from problem solving than by being told.	1	2	3	4	5

Nm	Mth	Almost Never	Seldom	Some times	Often	Almost Always
97	Mathematicians are about as fit and healthy as other people.	1	2	3	4	5
98	Mathematicians like sports as much as other people do.	1	2	3	4	5
99	Mathematicians can have a normal family life.	1	2	3	4	5
100	Mathematicians are just as interested in art and music as other people are.	1	2	3	4	5
101	If you met a mathematician, he would look like anyone else you might meet.	1	2	3	4	5
102	Mathematicians have enough time to spend with their families.	1	2	3	4	5
103	Mathematicians are as friendly as other people.	1	2	3	4	5
104	Mathematicians are happily married.	1	2	3	4	5

Scale Allocation and Scoring for TOMRA Items, Positive and Negative

Enjoyment of Mathematics Lessons	Attitude Towards Mathematics Inquiry	Normality of Mathematicians
81 (+)	89 (+)	97 (-)
82 (-)	90 (-)	98 (+)
83 (+)	91 (+)	99 (-)
84 (-)	92 (-)	100 (+)
85 (+)	93 (+)	101 (-)
86 (-)	94 (-)	102 (+)
87 (+)	95 (+)	103(-)
88 (-)	96 (-)	104 (+)

Positive items (+) are scored 5, 4, 3, 2, 1 respectively. Negative items are scored 1, 2, 3, 4, 5. Omitted or invalid responses are scored 3.

APPENDIX B

Parent Consent Letter

Consent to Participate in a Research Project
Ammons Middle School

Evaluating Online Resources in Terms of Classroom Environment and Student Attitudes in Middle-Grades Mathematics

James E. Earle
Mathematics Department Chair
305-971-0158 ext. 1203

Name of Student:____________________________________Grade Level_______

Purpose of Study: You have been selected to participate in a research project designed to assess the effectiveness of the online resource FCAT Explorer in terms of your perceptions and attitudes towards mathematics, and classroom environment that involves the factors of student cohesiveness, teacher support, involvement, investigation, task orientation, cooperation, equity, differentiation, computer usage, and young adult ethos.

Participation: You will be asked to complete two surveys as a pretest and the same two surveys as a posttest. One survey measures the classroom environment and the other survey measures attitude towards mathematics. These surveys will be taken during the Approaches to Learning Reading class. You may also be asked to take part in a brief interview regarding part or all of these topics at a convenient time and place, typically during a math class.

Risks: There are no risks involved in this study, nor will it negatively impact the classroom, instruction, or academic progress.

Benefits: The results of the individual surveys will be shared with you if you choose. As a result of the information gathered in the surveys, you may arrive at a better understanding of your perceptions and attitudes towards mathematics as well as inform our FCAT preparation activities at Ammons.

Compensation: No compensation shall be given for participating in this study. All responses will be on a volunteer basis.

Your Rights:

1. Participation in this research project is entirely voluntary. You may refuse to participate or withdraw from participation at any time without jeopardy to future employment, student status or other entitlements. The researcher may withdraw you at his professional discretion. It is understood that returning this letter is not required to participate in the project.
2. If, during this project, significant new information becomes available that may relate to your willingness to continue to participate, this information will be shared with you by the researcher.
3. Confidentiality will be protected to the extent provided by law.
4. If at any time you have questions regarding the research or your participation, you should contact me at the number provided at the top of this letter, and I will answer all questions you might have regarding the project.
5. If at any time you have comments or complaints regarding the conduct of this research or questions about your rights as a research participant you may contact the researcher as listed above or the principal of Ammons Middle School, Mr. Irwin Adler at 305-971-0158 ext. 4516.

____________________________________ Date____/____/____

Signature of Student/Subject

____

Signature of Parent/Guardian

____

Signature of Researcher

APPENDIX C

Interview Questions and Protocol

Method for choosing students to be interviewed: Students are chosen on the basis of their volunteering to participate in an interview about FCAT Explorer and their thoughts about mathematics

Introduction (Interviewer): Hi. How are you today? Thank you for speaking with me today. My name is Jim Earle and I'm gathering information for my doctoral research.

I'm investigating the effectiveness of the FCAT Explorer program in terms of student perceptions towards classroom environment and how they feel about math. Do you remember the surveys that you took a few weeks ago? This project started with those surveys. Don't worry, there are no right or wrong answers, and this is not for a grade. I'm just trying to get a clearer picture about what came out on the surveys by talking directly with students. Shall we begin?

Questions:

1. What is your name?
2. What grade are you in?
3. What math class are you taking this year?
4. What math class did you take last year?
5. Describe the things your math teacher does to help you learn math.
6. Describe how you solve math problems.
7. How important is it to you to work with other students when you do math?
8. Describe how you feel about using the computer to work on math problems.
9. Describe some of the things you like about math class.
10. Here is my final question. You used the FCAT Explorer for almost 3 months this year to prepare for the FCAT test. Describe the biggest way using the FCAT Explorer has changed your attitude about math.

Exit

Thanks for helping me. Are there any other thoughts about this interview or the FCAT Explorer that you'd like to share with me? Thanks again, and I appreciate your taking the time to help me.