Science and Mathematics Education Centre

Effectiveness of MAEA's Interactive Science Programs in Terms of African-American Students' Attitudes and Classroom Learning Environment

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DECLARATION

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

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Date: August, 2014

ABSTRACT

The major purpose of this study was to evaluate the relative effectiveness of exposure to hands-on Minority Aviation Education Association Inc. (MAEA) Interactive Science Programs among disadvantaged African-American students. The sample consisted of 268 8th grade students attending one experimental school and two comparison schools in Columbus, Ohio. The students in the intervention group were given monthly hands-on science instruction that followed their school's curriculum, where as the two comparison schools received no outside intervention.

The criteria of effectiveness were five learning environment scales from the What Is Happening In this Class? (WIHIC) questionnaire and two student attitude scales from the Test of Science-Related Attitudes (TOSRA). The scales selected from the WIHIC were Cooperation, Teacher Support, Involvement, Investigation and Task Orientation and the TOSRA scales chosen were Attitude to Scientific Inquiry and Enjoyment of Science Lessons.

Principal axis factor analysis with varimax rotation and Kaiser normalization, which was conducted separately for pretest and posttest data and separately for the WIHIC and TOSRA, supported the a priori five-scale structure of the WIHIC and two-scale structure of the TOSRA. The total proportion of variance accounted for was 60.64% for the pretest and 59.68% for the posttest for the WIHIC and was 69.58% for the pretest and 66.81% for the posttest for the TOSRA. The internal consistency reliability, using Cronbach's alpha coefficient for different WIHIC and TOSRA scales ranged from 0.78 to 0.94 for the pretest and from 0.80 to 0.94 for the posttest.

Whereas pretest–posttest changes were statistically significant and small in magnitude for every learning environment and attitude scale for the comparison group, MAEA students reported a statistically significant increase in scores between pretest and posttest for Cooperation, Teacher Support, Attitude to Scientific Inquiry and Enjoyment of Science Lessons. For these four scales for MAEA students, effect sizes were moderate in magnitude and ranged from 0.32 to 0.46 standard deviations. These results tentatively support the effectiveness of MAEA.

Past research was replicated in that a more positive classroom environment was associated with more positive attitudes to science. In particular, Teacher Support was a significant independent predictor of Enjoyment of Science Lessons, Involvement and Investigation were significant independent predictors of Attitude to Scientific Inquiry, and Task Orientation was a significant independent predictor of both Enjoyment of Science Lessons and Attitude to Scientific Inquiry.

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It takes a village to raise a child. It took my whole tribe to come together with words of encouragement and support to help me to complete the journey that was this doctoral thesis. It might say Darryl Baynes on the first page of this thesis, but it was the Baynes family who helped at every step along the way. First, I would like to thank the women in my life who have been supportive and encouraging throughout the whole process. My wife, my mother, my mother-in-law and my daughter all have given me their words of support, wisdom and strength when I didn't even have enough time to pay attention much less work on my thesis. Secondly, the men in my life, my father, father-in-law and my sons all helped me to keep my eye on the prize.

I am most appreciative and grateful for the support and guidance I have received from Dr Barry Fraser, who served as my thesis advisor and number one editor-in-chief. His expertise and experience of many years in the field made the whole experience not only more valuable, but more bearable. I am also grateful for the assistance of other members of the Curtin University Science and Mathematics Education Centre who have helped over the years, not just in this one piece of work but in the whole process. Dr David Treagust, Dr Jill Aldridge and Dr Darrell Fisher led me through the whole process of meeting all of the requirements of the program. To the entire SMEC team, I give my undying appreciation and thanks.

I would also like to thank the other students in the program who were working on their theses, at the same time but at different stages, who let me know that it was indeed possible to complete the journey on which I had embarked. Along the way, some of the other students have struggled and fallen to the way-side but, even in their struggles, they had words of support and encouragement for me.

I also have unwavering appreciation for the administrators of the schools who allowed me to be part of their lives and the lives of the students in their charge for an entire school year. The support of Principal Sharri Edwards from the intervention school has left us close friends to this day even though she has moved on the other schools. I would like to thank the 8th grade students who went on the journey of scientific exploration with me each month. They greeted me with smiles, hugs and words of excitement that made me know that I was not wasting their time in the classroom.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION AND RESEARCH OBJECTIVES

Live as if you were to die tomorrow. Learn as if you were to live forever. (Mahatma Gandhi)

1.1 CHAPTER INTRODUCTION

This thesis reports an investigation of the relative effectiveness of some interactive science programs developed by MAEA (Minority Aviation Education Association) when used with economically disadvantaged African-American students. A distinctive feature of this study is that one of my research questions involved employing student perceptions of their learning environments as criteria in evaluating the relative effectiveness of MAEA. A preliminary research question involved the validation of the learning environment and attitude questionnaires used with my sample of African-American students. A third research question involved associations between the classroom learning environment and students' attitudes to science. Section 1.3 in this chapter is devoted to a fuller consideration of my research aims.

When students initially enroll in a school in the Columbus City School District (where my study was conducted), their parents designate their children's ethnicity by selecting from a list of alternative ethnicities (e.g. African-American). Economic disadvantage in this District is defined by family income guidelines: if a student qualifies to receive the District's free or reduced-priced lunch, then this student is classified as being economically disadvantaged.

This chapter sets the scene for the rest of the thesis by, firstly, considering my own background, especially my involvement with MAEA, and how this background led me to initiate the current research (Section 1.2). Secondly, my study's three aims are delineated (Section 1.3). Thirdly, Section 1.4 identifies the significance of my study and clarifies the context of my study in terms: the Columbus City Schools district from which schools were selected; inquiry-based science teaching which underpins MAEA programs; and the field of learning environments which provided concepts and methods for my study.

1.2 MY PAST, PRESENT AND FUTURE: MAEA INTRODUCED

Over 20 years ago, soon after I founded the Minority Aviation Education Association (MAEA) which was incorporated in 1992, I wrote: "We are all scientists; we wonder, question and test our theories about the world. An understanding of science is nothing more than an understanding of ourselves." MAEA, a non-profit corporation, has developed into one of the largest science and mathematics outreach companies in the United States and the largest company owned and operated by African Americans. Over the past 20 years, MAEA has developed over 120 Interactive Science Programs designed to get young people excited about science and mathematics.

MAEA staff are passionate about our work with young people and, each year, this passion fuels our energy to travel across the country sharing our love of science with tens of thousands of students. We have made it a goal to lay a foundation that will catapult these young minds into their own explorations into science and mathematics. It is a privilege and a pleasure to watch their faces light up as they begin to understand complex concepts. Their responses reassure us that our work is having an impact and that we have successfully developed a way to speak in their language.

The journey of our growth has been fascinating and at times trying, but it is full of well-invested sacrifices. Our success can be measured not only by the number of students upon whom we impact, but also by the fulfillment of my own dreams that I've carried since my youth. Frederick Douglas said: "Judge me not by the heights to which I have soared, but rather from the depths from which I have come."

As a young boy growing up in Philadelphia during the 1960s, I had an intimate love of science and aviation. My love of science and aviation, partnered with a mother who supported me with mail-order science kits and trips to airports and science museums, developed strong roots for my future. My mother always told me that there wasn't anything I couldn't do…and I believed it.

Some of my most vivid memories were our trips to the Benjamin Franklin Institute. The displays, exhibits and live demonstrations excited my imagination. But I also remember that there were no African-Americans and no women performing the experiments. The lasting effect of that experience is strong because I did not see anyone who looked like me doing what I wanted to do, namely, conducting experiments. I kept my interest in science, determined to make a change. Of course, I was in elementary school during these formative years, but nothing that happened in school left as much of an impression on me as places to which I was taken and the experiments that I undertook at home. It was these places of interest and opportunities to interact that formed the learning environment that I so needed to allow me to develop the positive attitudes toward science that have persisted to this day.

It was not until I began high school that I started to have an opportunity to touch and feel science in a school setting. I remember every science class that I had because most of them were accompanied by a laboratory activity. If I had not experienced the exposure that my mother made available to me when I was younger, I might not have been able to appreciate the opportunities that I was afforded in high school.

In 1979, I accepted an athletic scholarship to the University of Pittsburgh where I immediately began taking science classes. My entry-level science classes were fairly evenly distributed, with half of the students in the class being either African-American or female. These numbers thinned with successive classes. By the time I reached upper-level science courses, I was the only African-American left and there were only a few females still holding on. As graduation came near in 1985, my athletic scholarship ran out when I was three classes short of a degree.

I began working to earn money right away, but still I was determined to fulfill my dreams of being a scientist and an aviator. I took a night job at the Post Office and started my entrepreneurial endeavors during the day. I owned real estate, a limousine company and an under-21 dance club. It was my goal to use the money from my business ventures to fund my flying dreams. I was working hard, but not working smart. Then an important part of the puzzle fell into place when I met and married my wife, Linda. She helped me to work smarter and focus on my goals rather that multi-tasking so much.

Often people of color are given messages, from society, the media, figures of authority or even their own homes, that they can't compete and that some things are just too hard for them to understand. This not only happens to people of color, but also to people of lesser financial means or backgrounds. Unfortunately, these are the same people who cannot afford negative messages from any source. How can people, who are systematically fed negative messages about their abilities and not given opportunities to develop a positive attitude toward accomplishments in science, ever hope to be part of that world?

With encouragement from my wife, I started taking flying lessons. When I started attending flying school, I was the only African-American. There was one woman taking lessons. Her husband was rich and funded all of her training; she now flies for a major airline carrier. I learned through this time of trial that, "no matter what your dream is, the reality often is that there are the Haves and the Have-nots. It is hard for the Have-nots to become the Haves. The Haves already have or can create an environment where learning can take place. Years of exposure to opportunities and support help to create a positive attitude. Educational environments that allow learning to take place help to build the foundation for the future.

The next step came as I joined the Civil Air Patrol and became the Education Officer for the Group 60 Civil Air Patrol Wing in Pennsylvania. The position allowed me to help myself and other people with the dream of flying. I began taking groups of students to the Greater Pittsburgh International Airport Control Tower and providing aviation-related programs in schools. I was now in a position to help to expose young people to the world that had passed most of them by. During this time, I met a Federal Aviation Administration employee named Tom Lawson, who became interested in our activities. Together with my wife, we incorporated the Minority Aviation Education Association (MAEA). The goal of the organization is to encourage more minorities and women to pursue aviation and aviation-related careers. I now had an official name to go with our activities in schools. I received my private pilot's license in 1993, thus fulfilling one of my dreams.

I returned to the University of Pittsburgh to complete my degree in science. Another part of the puzzle fell into place when I met Dave Dimellio and Gary Warnock, who coordinated the Science Outreach Van Program at the University of Pittsburgh. They invited me to come to see one of their programs. There was excitement among the students, but I noticed that the two men were talking over the heads of the students. They were showing high-school concepts to elementary-age students who had not yet been introduced to much science. I found myself interpreting what they were saying in a way in which children could understand. I felt that these children benefited from seeing a person of color there and having me explain what was going on. That started the next phase of the MAEA's evolution.

We began another division of outreach, called MAEA Interactive Science Programs, in response to the under-representation of minorities and women in all of the fields with a mathematics and science focus. We expanded beyond our initial aviation-related programs to embrace the principles of biology, chemistry, physics and other areas. Currently, we offer approximately 120 programs spread between in-school programs, after-school programs, field trips and science camps.

With persistence, anything can be overcome. It's hard for a Have-not to become a Have because of many factors. One of these factors is the number of years of constant negativity which leaves the Have-nots in a position of learned helplessness, self-doubt and low self-esteem. The Have's can count on support from most aspects of their environment. It is this same environment that sends out the opposite messages to the Have-nots. The key word to remember is persistence. Someone said: "If you knock loud enough and long enough, someone will answer." Many of the children in the state of West Virginia where I live have been put in the same boat as their counterparts in the inner city: you come from Have-nots, and you'll remain in that condition because you deserve no better!

Our objectives for MAEA were established and remain as follows:

- To educate students, teachers and the community regarding the history of minorities in the field of science, mathematics and technology in order to provide role models.
- To expose minority students to the major sciences through practical applications and demonstrations, thereby educating them about the relevance of science in everyday life, with the intention of stimulating future career interest.
- To help students who are interested in science, mathematics, engineering, computer science or any related technological fields to secure financial assistance, thus enabling them to pursue post-secondary education.
- To increase the numbers of minorities and females employed in commercial aviation, science, mathematics and high-tech fields in which they have been traditionally under-represented.

Our programs were getting so popular that my wife and I decided that it was time to 'take the road less traveled'. So, after 10 years of service, I asked the Post Office for a leave of absence, but I was turned down. Because I was left with no choice, after the Christmas rush in 1996, I left and never looked back. I was then a full-time employee for MAEA and began to travel throughout the U.S. because our programs were getting so popular. It was then my full-time job to create positive learning environments for inner-city and at-risk youth, with the aim of helping them to develop positive attitudes toward science.

The success that we have enjoyed is soundly rooted in our belief that we could succeed. It was this belief in our own potential that required us to prepare for our future as we guided its direction. Whitney M. Young said that "it is better to be prepared for an opportunity and not have one, than to have an opportunity and not be prepared". An understanding of the necessity to prepare came from our internal belief that we could succeed.

In January 1998, MAEA hired Tyrone Green, who has excellent rapport with students. He and I provided 250 programs to over 67,000 students, teachers and parents in 1998. The organization was running like a well-oiled machine by this time as we continued to expand to Tennessee and Wisconsin and to 13 U.S. states overall. In the following year, we expanded our programming and began making plans for a permanent site. My wife and I chose Wheeling in West Virginia because we saw, and still see, the congregation of science-related and mathematics-related organizations and institutions in the area as providing a wealth of opportunity for partnerships and growth.

The new millennium arrived with a boom as did our sphere of outreach. We traveled to Colorado, Georgia, Florida and Indiana in addition to our already-existing territories. We presented almost 300 programs for close to 85,000 students, teachers and parents, thus becoming the largest science and mathematics outreach organization owned and operated by minorities in the U.S.

By 2001, over 70,000 people were participating in our programs. Our reach encompassed 20 states as we added Texas, Mississippi, and South Carolina. As a result, MAEA provides more outreach programs than the Carnegie Science Center, Carnegie Mellon University or the University of Pittsburgh, which gave us our roots. Figure 1.1 shows the number of participants in MAEA programs annually for each year between 1995 and 2012.

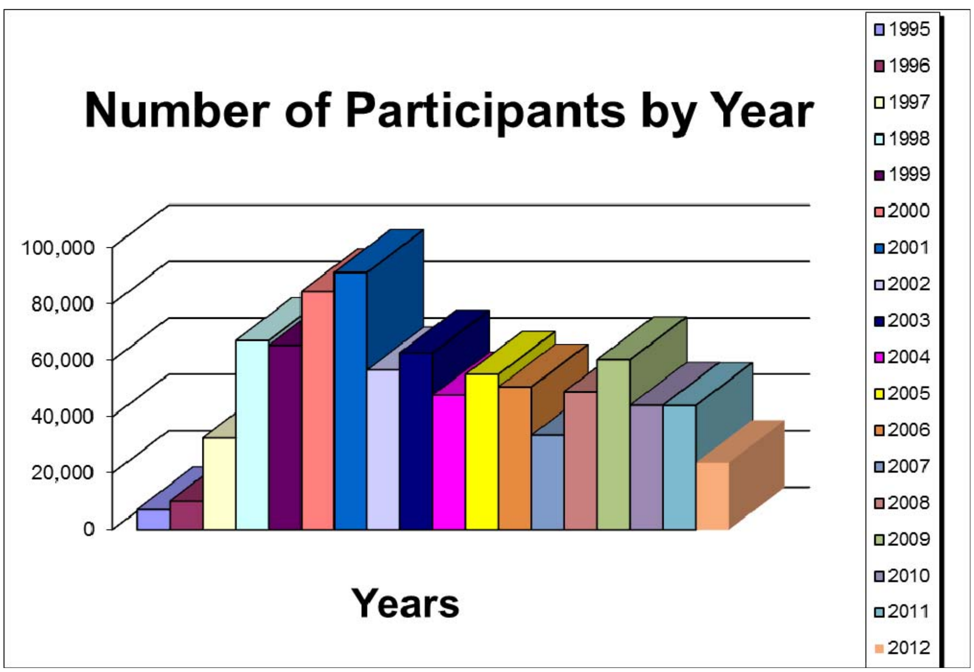

Figure 1.1 Number of Participants in MAEA Program Each Year During 1995–2012

MAEA and now Interactive Science Programs provide more outreach than those institutions whose staff wouldn't give us a place at the table, but wanted to keep us in the kitchen. We are showing the Have-nots of this country that there is a place for them, not by preaching at them, but by showing them through example. Someone said "Give me a fish and I will eat for a day, but teach me to fish, and I will eat for a life time". By creating these positive learning environments for students and helping them to develop positive attitudes in science, we are essentially teaching them how to fish. Further information about MAEA's interactive science programs can be found at www.maeasciencecenter.org and www.Interactivescienceprograms.org.

1.3 CURRENT STUDY AND ITS AIMS

Over the years, it has been my goal and MAEA's goal to create positive learning environments for students and thus help to foster positive attitudes toward science. This goal provided the motivation for this research. Given the history of MAEA as described above in Section 1.2, including its remarkable involvement of hundreds of thousands of students, it was important for me to undertake an evaluation of its effectiveness. Consequently, the next step in my journey with MAEA was to enroll in a PhD degree as a way of conducting such an evaluation under expert guidance.

In evaluating the relative effectiveness of MAEA's Interactive Science Programs in terms of African-American students' perceptions of classroom learning environment and attitudes, it was my hope to be able to use the results of this research to show other educators how implementation of hands-on science techniques can improve students' attitudes toward science by creating positive science classroom learning environments.

Following my extensive review of literature, as provided in Chapter 2 of this thesis, I decided to follow much past research by choosing a learning environments framework for my evaluation of MAEA. Additionally, for my specific target population of disadvantaged African-American students, I considered that it was particularly important to investigate students' attitudes to science as criteria of the effectiveness of MAEA.

While the evaluation of MAEA in terms of its impact on the learning environment and student attitudes was the main purpose of my study, there were two other secondary aims. Because past research seldom has specifically involved samples of African-American students, my second research goal was to cross-validate the questionnaire used for assessing the classroom environment and student attitudes.

My third research aim involved investigating associations between the classroom learning environment and students' attitudes to science. The last aim potentially could have practical implications concerning how to improve African-American students' attitudes by changing the classroom environment.

In summary, my three research aims were:

1. To validate the What Is Happening in this Class? (WIHIC) questionnaire and Test of Science Related Attitudes (TOSRA) when used with disadvantaged African-American middle-school students.
2. To evaluate the relative effectiveness of MAEA in terms of students:
    a) perceptions of classroom learning environment

b) attitudes to science.

3. To investigate associations between the classroom environment and students' attitudes to science.

1.4 SIGNIFICANCE AND CONTEXT OF STUDY

The significance of my study is briefly established below in Section 1.4.1. My study's context is illuminated in terms of the school district from which my sample was drawn in Columbus (Section 1.4.2) and the nature of inquiry-based science teaching (Section 1.4.3) which underpins MAEA instructional programs. Finally, because my study was situated within the field of classroom learning environments, this field is briefly introduced in Section 1.4.4.

1.4.1 Significance

This study was significant within the field of learning environments because, as demonstrated later by the comprehensive literature review in Chapter 2, hardly any prior learning environment studies have involved samples of African-American students. Therefore, my research provided the opportunity to cross-validate existing questionnaires with the particular group and to attempt to replicate past findings of significant associations between students' attitudes and the classroom environment.

My research was also significant because it provided the first formal evaluation of the relative effectiveness of the innovative educational program

MAEA. Because this program has previously reached hundreds of thousands of students, it was timely and important to evaluate it.

A third distinctive feature of my study was its context. In the schools and in the school district where my research was conducted, virtually all students were classified as disadvantaged (i.e. they qualified for the school district's program of free or reduced-cost lunch). Therefore, my study had the potential to yield practically-useful implications for improving the science education of disadvantaged students.

1.4.2 Columbus City School District

Because my study was conducted in schools in the Columbus City School district, it is important to illuminate the context of my study by briefly providing some background information about this district.

The state in which my study took place was Ohio, which is located in mid-west USA, is the seventh most-populous state, and is the 34th largest state in area. Ohio is one of 18 of the 52 US states with a population of African-Americans that exceeds one million. Public schools in Ohio cater for almost 2 million students.

The city in which my study took place was Columbus, which was founded in 1812 and named after the explorer Christopher Columbus. The metropolitan area of Columbus is the third largest in Ohio, behind Cleveland and Cincinnati. However, the proportion of students who are economically disadvantaged is higher in Columbus than in either Cleveland or Cincinnati.

The specific school district where my study took place is called the Columbus City School District. Currently it caters for over 50,000 students, of whom almost 60% are African-American and who speak 89 different languages at home (www.columbus.k12.oh.us).

The three middle schools that participated in my study are located in neighborhoods that are comparable in terms of economic status, home ownership, ethnic composition, etc. Because most parents in these neighborhoods typically have limited education, they don't always appreciate the importance of their children's education. The proportion of African-American students in the schools in my study is about 20% higher than for the Columbus City School District as a whole. The neighborhoods in which my study's schools were located are typical of other inner-city school districts in the USA, but less representative of the whole Columbus City School District. Further details about my sample are provided later in Chapter 3, Section 3.2.

In order to clarify the nature of the grade 8 science curricula in the Columbus City School District, I informally interviewed the district's Assistant Superintendent, Director of Middle School Science, and the science teachers involved in my study. The feedback from interviews with all of these people consistently confirmed several patterns related to the district's middle-school science curriculum:

- Curriculum documents clearly specify a policy for science programs that involves extensive use of hands-on and inquiry teaching approaches.
- Despite the rhetoric of official curriculum documents, the reality is that about 50% of science teachers seldom use inquiry methods, approximately

40% sometimes use inquiry methods, and only about 10% of science teachers consistently and regularly use these methods.

- The major impediments to the use of inquiry methods are considered to be a lack of adequate equipment and suitable teacher professional development concerning hands-on teaching methods.

Given this context, the time was ripe to implement inquiry-based science teaching in this district and to evaluate its effectiveness.

1.4.3 Inquiry-Based Science Teaching

A brief history of the advocacy and use of inquiry in science teaching and learning is provided by Barrow (2006). Early in 1900s, John Dewey (a former science teacher) was advocating the inclusion of inquiry in the school science curriculum (Dewey, 1910, 1971). Dewey considered that there was too much emphasis on the memorization of facts and insufficient emphasis on science as a process and as way of thinking. Dewey encouraged science teachers to use inquiry as a teaching strategy involving the scientific method consisting of six steps: sensing challenging situations, clarifying the problem, formulating a hypothesis, testing the hypothesis, revising with rigorous tests, and acting on the solution. In Dewey's model, the student is actively involved in the investigation and the teacher acts as facilitator and guide.

In the 1960s, the foundations of inquiry teaching and learning were laid by Suchman (1962) and Schwab (1962). Suchman's 'inquiry training' was developed as an instructional model which could be used to teach students a process for investigating phenomena by participating in scientific inquiry. This technique is based on the belief that individuals are naturally inquisitive and it emphasizes the tentative nature of all knowledge by encouraging the development of alternative explanations for observed phenomena (Joyce & Weil, 1986). The introduction of inquiry into science education owes much to the work of Schwab, an educator who promoted inquiry science as a process of thinking and learning in which classroom activities align with the work carried out by research scientists. Schwab (1966) developed three levels of inquiry: (1) students are provided with questions, methods and materials and are challenged to discover relationships between variables; (2) students are provided with a question, and develop a method for research on their own; and (3) phenomena are proposed and students undertake their own research to discover relationships among variables.

A half a century ago, fundamental changes in science education in the United States involved the development of inquiry-based curricula, following a pattern established by the Biological Sciences Curriculum Study (BSCS) and CHEM study, among others. Following trials in schools in 1960–1962, BSCS materials were introduced into American high schools in 1963 (Biological Sciences Curriculum Study & Klinckmann, 1970). The launch by the Soviet Union of the satellite Sputnik in 1957 had a galvanising effect on science education reform in the United States and, in 1966, the National Science Education Standards (1966) outlined six important aspects pivotal to inquiry learning in science education:

1. Students should be able to recognize that science is more than memorizing and knowing facts.

2. Students should have the opportunity to develop new knowledge that builds on their prior knowledge and scientific ideas.
3. Students develop new knowledge by restructuring their previous understandings of scientific concepts and adding new information learned.
4. Learning is influenced by students' social environment and therefore they have an opportunity to learn from each other
5. Students take control of their learning.
6. The extent to which students are able to learn with deep understanding influences how transferable their new knowledge is to real-life contexts.

Project Synthesis, funded by the National Science Foundation in the USA between 1955 and 1975, provided content and teaching strategies to assist science teachers in the use of inquiry in science instruction (Welch, Klopfer, Aikenhead & Robinson, 1981).

In the 1990s, advocacy of inquiry in science education continued (Haury, 1993; Hinrichsen & Jarrett, 1999; Metz, 1998), especially with the National Science Education Standards giving considerable emphasis to science as inquiry (National Research Council, 1966, 2000). Again, in the most-recent 'next generation' science standards, inquiry-based science education is central (National Research Council, 2013). Clearly, inquiry-based science teaching continues its importance in science education today (Lederman & Lederman, 2012).

Bybee (2004) has clarified aspects of scientific inquiry and drawn out implications for science teaching. Overall, Bybee is a strong advocate for inquiry-based science teaching.

The ideas of constructivism have been dominant in science education for decades (Staver, 2012; Taylor, 1998; Tobin, 1993). Furthermore, in inquiry-based science education, inquiry practices often have been built on constructivist perspectives (Berry & Loughran, 2012; Harlen, 2010). According to Green and Gredler (2002), social constructivism links learning to the activities in which students are engaged, whereas holistic constructivism begins with major concepts and then breaks them down into smaller parts. In successful constructivist or inquiry-based teaching, students' prior knowledge must be taken into account (Hess & Trexler, 2005). Of course, for teachers to teach effectively using constructivist or inquiry approaches, teacher professional development is needed (Mintrop, 2001).

Abell (1999) has provided four descriptive stories of inquiry learning that all relate to Dalton and Morocco's (1997) common inquiry steps of engage, explore, explain, apply and evaluate. Krajcik et al. (1998) reported a seven-month study of seventh-grade students in inquiry settings. Metz (1988) explains how young children can design and implement experiments, thereby developing knowledge and improving their inquiry processes.

Since its introduction into science classrooms, inquiry teaching and learning has been subject to criticism from both practitioners and researchers from both pragmatic and philosophical viewpoints (Barrow, 2006). Anderson (2002) classifies the barriers to the implementation of inquiry as being of three kinds: technical (e.g., the implementation of group work); political (e.g., lack of available resources for teachers to use); and cultural (e.g., teachers' differing views about the purposes of assessment).

Inquiry-based teaching methods require a great deal of planning on the part of the teacher (Bell, Urhahne, Schanze & Ploetzner, 2010) and pose challenges such as the management of extended investigations and the provision of adequate resources for students (Edelson, Gordin & Pea, 1999). Whilst some researchers cite a lack of evidence for the efficacy of inquiry-based teaching (Kirschner, Sweller & Clark, 2006), others have provided evidence of desirable student outcomes (Hmelo-Silver, 2004; Magnussen, Ishida & Itano, 2000). Although the National Science Education Standards (1996) promoted the use of inquiry-based teaching, it has been suggested that this approach has been overemphasized and that teachers are concerned about the amount of time needed to teach essential content in preparing students for fact-oriented science tests (Tonsho, 2006).

Various studies have employed learning environment criteria in evaluating inquiry-based science programs and have provided evidence to support their effectiveness. In Australia, Maor and Fraser's (1996) study supported the effectiveness of inquiry-based computer-assisted learning among middle-school students. In California, Martin-Dunlop and Fraser (2008) reported that a positive learning environment was associated with an innovative inquiry-based university science course designed for prospective elementary teachers. In New York, Wolf and Fraser's (2008) research supported the efficacy of inquiry-based science laboratory activities among middle-school science students. In Florida, Lightburn and Fraser (2007) provided evidence of the effectiveness of using anthropometric activities among high-school science students in terms of classroom environment and student outcomes.

1.4.4 Field of Classroom Learning Environments

Because my study was based on and contributed to the field of classroom learning environments, most of my literature review in Chapter 2 focuses on research conducted in this field from around the world. However, a brief introduction to the field of learning environments is provided here.

The foundations of the field of learning environments were laid in the late 1960s and early 1970s in the USA by Herbert Walberg and Rudolf Moos. Whereas Walberg developed the Learning Environment Inventory (LEI) as part of the research program of Harvard Project Physics (Walberg & Anderson, 1968), Moos developed the Classroom Environment Scale (CES) as one of nine somewhat similar instruments for assessing different human environments (Moos, 1974; Moos & Trickett, 1974). In turn, the work of Walberg and Moos built on seminal ideas from non-educational settings proposed by Lewin (1936) and Murray (1938). For example, Lewin hypothesized that behavior is a function of both the person and the environment.

In the four decades since the significant contributions of Walberg and Moos, the field of classroom learning environments has experienced remarkable expansion, diversification and internationalization. These developments are synthesized in various literature reviews (Fraser, 1998a, 2007, 2012, 2014) and books (Aldridge & Fraser, 2008; Fisher & Khine, 2006; Fraser, 1986; Fraser & Walberg, 1991; Khine & Fisher, 2003; Wubbels & Levy, 1993).

Few fields of educational research can boast the rich array of validated questionnaires that are available to assess learning environments (Fraser, 1998b, 2012). Many of these questionnaires are reviewed in Chapter 2 of this thesis. The common feature of these questionnaires is that they assess students' perceptions of psychosocial characteristics of their classroom environments. For example, the questionnaire chosen for my research, the What Is Happening In this Class? (WIHIC), assesses the dimensions of Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, and Equity (Aldridge, Fraser & Huang, 1999).

One of the main traditions in past learning environment research has involved evaluating educational innovations/programs in terms of their success in transforming the classroom environment. For example, learning environment criteria of effectiveness have been used in past studies in evaluating outcomes-focused education (Aldridge & Fraser, 2008), Student Response Systems (Cohn & Fraser, 2013), National Board Certification (Helding & Fraser, 2013) and mathematical games (Afari, Aldridge, Fraser & Khine, 2013). In my study, I used dimensions assessed by the WIHIC in evaluating MAEA's interactive science programs.

Another strong tradition in past learning environments research has involved associations between student outcomes and the nature of the classroom environment (Fraser, 2012; Fraser & McRobbie, 1995; Goh, Young & Fraser, 1995). In my study, I investigated bivariate and multivariate relationships between scores on WIHIC scales and students' attitudes to science.

1.5 OVERVIEW OF OTHER CHAPTERS

Chapter 2 provides a comprehensive review of literature relevant to my study. Because my research drew on the field of classroom learning environments, this chapter provides a historical perspective on this field and considers a range of validated and robust questionnaires for assessing students' perceptions of their learning environments. Also past research involving classroom environment instruments is reviewed according to: types of past studies; and studies in different countries/regions of the world. Finally, because my study also involved student attitudes to science, literature relevant to this topic also is reviewed.

Chapter 3 is devoted to describing and justifying my research methods. Details are provided about the sample of students and schools involved and the questionnaires used to assess classroom environment (What Is Happening In this Class?, WIHIC and Test of Science Related Attitudes, TOSRA). As well, the methods of data analysis chosen to answer each of my research questions are discussed.

Chapter 4 reports the results of the data analyses that were carried out in order to answer my three research questions concerning: the validity of questionnaires; the relative effectiveness of MAEA programs; and associations between learning environment and student attitudes.

Chapter 5 concludes this thesis by summarizing previous chapters, identifying limitations of this research, suggesting desirable directions for future research, and drawing out the implications and contributions of my study.

Chapter 2

LITERATURE REVIEW

> Just as in any workplace, if you do not enjoy coming to work, then it becomes more difficult each day to come to focus and in the case of students to learn and prosper. (Lee Edward Riddle)

2.1 CHAPTER INTRODUCTION

My evaluation of MAEA interactive science programs mainly drew on the field of learning environments for concepts, assessment instruments, and methods, and was guided by the voluminous body of past research on classroom environment around the world. As well, this evaluation involved student attitudes to science as criteria of effectiveness.

Because my study is quite unique in its application of ideas from the field of learning environments specifically with African-American students, it was important and appropriate to base this literature review on the voluminous past research on learning environments with samples involving students from around the world who are not African-Americans. Although my study involved no element of international comparison, nevertheless, my literature review attempted to achieve both completeness and an important international perspective by encompassing all relevant past research from all countries in which it was conducted.

This chapter is devoted to reviewing literature primarily from the field of learning environments, but also secondarily on student attitudes and inquiry-based science instruction, using the following structure:

- Section 2.2 Field of learning environments
- Section 2.3 Learning environment questionnaires
- Section 2.4 Types of past research on classroom learning environments
- Section 2.5 Past learning environments research in different countries
- Section 2.6 Student attitudes to science
- Section 2.7 Summary.

2.2 FIELD OF LEARNING ENVIRONMENTS

Learning environments can be defined as the "characteristics related to providing a physical, intellectual and socio-psychological environment that combine to either positively or negatively affect the educational process of the learner" (Collins & O'Brien, 2003, p. 262).

Because students spend a huge amount of time in classrooms – approximately 20,000 hours by the time when they graduate from university (Fraser, 2001) – the quality of classroom life is important in its own right. However, despite its importance, researchers and practitioners often rely too much on student outcomes, especially achievement. The field of classroom learning environments provides one approach for conceptualising, assessing, investigating, and improving what goes on in classrooms. Furthermore, extensive research with students around the world provides consistent and convincing evidence that the classroom environment influences students' outcomes, including achievement (Fisher & Khine, 2006; Fraser, 1986, 2007, 2012). Therefore, having a positive classroom environment can be considered both a worthy end itself and a means to valuable ends (i.e. improved student outcomes).

The historical beginnings of contemporary learning environments research usually are attributed to Herbert Walberg and Rudolf Moos, who independently pioneered the use of participant perceptions of various learning settings. Research and evaluation related to Harvard Project Physics led to the development of the Learning Environment Inventory (LEI, Walberg & Anderson, 1968; Walberg, 1979). Moos (1974) developed a scheme for classifying human environments into three dimensions (relationship, personal development, and system maintenance and change) to enable the classification and sorting of various components of any human environment. This led Moos to the development of the Classroom Environment Scale (CES) (Moos, 1979; Moos & Trickett, 1974), which linked his work in other human environments to school settings.

This pioneering research on learning environments in the USA soon spread to Australia. Walberg's work on evaluating Harvard Project Physics inspired other researchers to incorporate the LEI, either in its original or a modified form, in their evaluations of the Australian Science Education Project (ASEP). Fraser (1979) compared the learning environment of ASEP and conventional classrooms among a sample of 541 Grade 7 students, whereas Fraser and Northfield (1981) monitored changes during the use of ASEP materials among 17 seventh-grade classes. This research replicated with Australian students the consistent associations between student outcomes and classroom environment reported in Walberg's studies in the USA.

Early research using the CES in Tasmania, involving 116 Grade 8 and 9 science classes, made several significant contributions to the emergence of learning environments research in Australia. First, the CES was crossvalidated for use in Australia (Fisher & Fraser, 1983a). Second, interesting patterns of differences were reported between students' and teachers' perceptions of actual and preferred classroom environment (Fisher & Fraser, 1983b). In particular, both students and teachers preferred a more favorable classroom environment than the one perceived to be actually present; and teachers perceived the same classroom environment more favorably than did their students. Third, associations were established between student outcomes (attitudes and inquiry skills) and the classroom learning environment (Fraser & Fisher, 1982). Fourth, in an innovative application of learning environment ideas, Fraser and Fisher (1983a, 1983b) utilised a person–environment fit perspective to establish that students' achieve cognitive and affective outcomes better when in their preferred classroom environment.

The first major questionnaire development undertaken in the field of learning environments in Australia focussed on the Individualised Classroom Environment Questionnaire (ICEQ), which grew out of awareness that both the LEI and CES assessed the environment of teacher-centered classrooms and were not ideal for student-centered, individualised and inquiry-based settings. Its five dimensions (Personalisation, Participation, Independence, Investigation and Differentiation) assess those dimensions that distinguish individualised classrooms from conventional ones (Fraser, 1990; Rentoul & Fraser, 1979). The ICEQ was used in investigating relationships between student outcomes and the nature of the classroom environment (Fraser & Fisher, 1982), as well as differences between actual and preferred perceptions and between students' and teachers' perceptions with a sample of 116 classes in Tasmania (Fisher & Fraser, 1983b).

Simultaneously with this research in Australia, another program of learning environments research emerged in The Netherlands. Wubbels and his colleagues began a program of research focusing specifically on the interactions between teachers and students in the classroom and involving use of the Questionnaire on Teacher Interaction (QTI; Wubbels & Brekelmans, 1998, 2005, 2012; Wubbels, den Brok, van Tartwijk & Levy, 2012; Wubbels & Levy, 1993). This questionnaire is based on a model of teacher interpersonal behavior that has the two dimensions of influence (dominance–submission) and proximity (opposition–cooperation). Its eight scales assess Leadership, Helping/Friendly, Understanding, Student Responsibility/Freedom, Uncertain, Dissatisfied, Admonishing and Strict behavior.

A recent literature review (Wubbels & Brekelmans, 2012) describes some of the many past and contemporary accomplishments of this impressive and important program of research involving the QTI. As described later in this chapter, the QTI has been used in developing typologies of classroom environments in The Netherlands, the USA and Australia. An extensive study has identified changes in teacher interpersonal behaviour during the professional career, with teachers with 6–10 years of experience having the best relationships with their students in terms of promoting achievement and positive attitudes (Brekelmans, Wubbels & van Tartwijk, 2005). The research on teacher–student interaction involving use of the QTI has spread to many countries including Australia (Ferguson & Fraser, 1998;

Fisher, Henderson & Fraser, 1995), Korea (Kim, Fisher & Fraser, 2000), Brunei (Scott & Fisher, 2004) and Singapore (Goh & Fraser, 1998; Quek, Wong & Fraser, 2005a, 2005b).

The consolidation and long-term continuation of any new field requires structures to support it. Because the American Educational Research Association (AERA) sponsors the world's largest and most prestigious educational research conference, clearly, it was advantageous for learning environment researchers to have the opportunity to meet together and report their work in this forum. Therefore, in 1984, the AERA Special Interest Group (SIG) on Learning Environments was established. This highly-successful and widely-international SIG has sponsored its own program at every AERA annual meeting since 1985. In 2014, the AERA annual meeting program had 105 entries in its index under the heading 'learning environments'. The next landmark in the field's evolution was to establish a new journal devoted especially to learning environments research. The first issue of *Learning Environments Research: An International Journal* was published in 1998 by a leading international publisher, Springer (formally Kluwer). In 2014, this journal is in its seventeenth volume. More recently, a decade after the establishment of this journal, another landmark was the evolution in 2008 of a book series entitled Advances in Learning Environment Research sponsored by Sense Publishers (Aldridge & Fraser 2008; Wubbels, den Brok, van Tartwijk & Levy, 2012).

2.3 LEARNING ENVIRONMENT QUESTIONNAIRES

Because a remarkable feature of the field of classroom learning environments is the availability of a host of valid and widely-applicable questionnaires, this section is devoted to their review. Table 2.1 provides an overview of 11 historically-significant and contemporary classroom learning questionnaires. This table shows, for each questionnaire, the educational level for which it is appropriate, the number of items per scale, and the names of the constituent scales classified according to Moos' (1974) scheme.

2.3.1 LEI, CES, ICEQ and CUCEI

These four questionnaires, although historically significant, are seldom used in contemporary studies. As noted above, the Learning Environment Inventory (LEI) was one of the first learning environment questionnaires and it was developed by Walberg and Anderson (1968) as part of the research and evaluation program of Harvard Project Physics. Similarly, the Classroom Environment Scale (CES) was one of nine parallel questionnaires developed by Moos (1974) to evaluate a wide variety of human environments. The Individualised Classroom Environment Questionnaire (ICEQ) was developed by Rentoul and Fraser (1979) as the first learning environment instrument to focus on student-centered classrooms.

Surprisingly little work has been undertaken in higher education classrooms which is parallel to the traditions of classroom environment research at the secondary- and elementary-school levels. Consequently, the College and University

Classroom. Environment Inventory (CUCEI) was developed for use in small classes (of up to 30 students) sometimes referred to as 'seminars' (Fraser & Treagust, 1986; Fraser, Treagust & Dennis, 1986). The final form of the CUCEI contains seven, seven-item scales. Each item has four responses (Strongly Agree, Agree, Disagree, Strongly Disagree) and the polarity is reversed for approximately half of the items. In an evaluation of alternative high schools, Fraser, Williamson and Tobin (1987) used the CUCEI with 536 students in 45 classes to identify more involvement, satisfaction, innovation and individualisation in the alternative schools. Working in computing classrooms in New Zealand, Logan, Crump and Rennie (2006) used the CUCEI and found that its psychometric performance was not ideal.

2.3.2 My Class Inventory (MCI)

Although the LEI is historically significant, it is no longer used much in contemporary learning environment research. However, the My Class Inventory (MCI), a simplified version of the LEI for children aged 8–12 years, is still used today because of its unusually low reading level. The MCI, which has only five scales and simplified wording, has been validated in Australia (Fisher & Fraser, 1981; Fraser & O'Brien, 1985) and Texas (Scott Houston, Fraser & Ledbetter, 2008). Also it has been modified, crossvalidated and used with large samples of 1565 lower-secondary students in Brunei (Majeed, Fraser & Aldridge, 2002), 2835 grade 4–6 students in Washington State (Sink & Spencer, 2005) and 1512 grade 5 students in Singapore (Goh & Fraser, 1998).

Table 2.1 Overview of Scales Contained in 11 Classroom Environment Instruments

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

Sink and Spencer (2005) advocated using the MCI as an accountability tool for elementary-school counsellors and cross-validated it with a large sample of 2835 grade 4–6 students in Washington state. In Texas, Scott Houston, Fraser and Ledbetter (2008) used the MCI to establish that using science kits was associated with a more positive classroom environment than alternative methods for a sample of 588 grade 3–5 students. In Florida, Mink and Fraser (2005) reported that a curriculum project that integrates science, mathematics and literature had a positive impact on the classroom environment.

2.3.3 Questionnaire on Teacher Interaction (QTI)

As mentioned in Section 2.2, programmatic research into teacher–students interactions was initiated in The Netherlands in the 1980s and subsequently spread to many countries around the world (Wubbels & Brekelmans, 1998, 2005, 2012). This research involved the use of the QTI which has eight scales based on a two-dimensional model of influence (dominance–submission) and proximity (opposition–cooperation). For example, Scott and Fisher (2004) undertook a major cross-validation of a Malay version of the QTI with a sample of 3104 students in 136 elementary-school classroom in Brunei Darussalam, whereas Brekelmans, Wubbels and van Tartwijk (2005) investigated changes in teacher interpersonal behaviour across the teaching career.

A shorter and more-economical English version of QTI was developed and validated with 1512 grade 5 mathematics students in Singapore (Goh & Fraser, 1996). In Korea, Lee, Fraser and Fisher (2003) cross-validated a Korean-language version of the QTI among 439 science students. In Indonesia, Fraser, Aldridge and Soerjaningsih (2010) cross-validated an Indonesian-language version of the QTI with 422 university students.

2.3.4 Science Laboratory Environment Inventory (SLEI)

Because of the importance of laboratory settings in science education, an instrument specifically suited to assessing the environment of science laboratory classes at the senior high school or higher education levels was developed (Fraser, Giddings & McRobbie, 1995; Fraser & McRobbie, 1995). The SLEI has five seven-item scales (Student Cohesiveness, Open-Endedness, Integration, Rule Clarity and Material Environment) and the five frequency response alternatives are Almost Never, Seldom, Sometimes, Often and Very Often. Typical items are “I use the theory from my regular science class sessions during laboratory activities” (Integration) and “We know the results that we are supposed to get before we commence a laboratory activity” (Open-Endedness).

The SLEI was field tested and validated simultaneously with a sample of 5477 students in 269 classes in six different countries (the USA, Canada, England, Israel, Australia and Nigeria) and later crossvalidated with Australian students (Fisher, Henderson & Fraser, 1997; Fraser & McRobbie, 1995). Subsequently, the SLEI was crossvalidated and used in other countries, including the USA with 761 high-school biology students (Lightburn & Fraser, 2007), Korea with 439 high-school students (Fraser & Lee, 2009), and Singapore with 1592 grade 10 chemistry students (Wong & Fraser, 1996).

As well as supporting the cross-cultural validity of the SLEI, these studies provided several other noteworthy findings. In Korea, Fraser and Lee (2009) reported that students in the science-independent stream perceived their science laboratory classroom environments more favorably than did students in either the science-oriented or humanities streams. In Florida, Lightburn and Fraser (2007) found that there was a positive influence when using anthropometric activities in high-school science. In Singapore, Wong and Fraser (1996) reported associations between the laboratory classroom environment and chemistry students' attitudes.

2.3.5 Constructivist Learning Environment Survey (CLES)

Taylor, Fraser and Fisher (1997) developed the CLES to assist researchers and teachers to assess the degree to which a particular classroom's environment is consistent with a constructivist epistemology, and to assist teachers to reflect on their epistemological assumptions and reshape their teaching practice. The CLES has 36 items, with five frequency response alternatives ranging from Almost Never to Almost Always, which assess Personal Relevance, Uncertainty of Science, Critical Voice, Shared Control, and Student Negotiation. Typical items are "I help the teacher to decide what activities I do" (Shared Control) and "Other students ask me to explain my ideas" (Student Negotiation). Taylor and colleagues (1997) reported sound validity for the use of the CLES with both Australian and American students.

Later, the CLES was crossvalidated in science classes with 1079 students in 59 classes in Texas (Nix, Fraser & Ledbetter, 2005), 739 grade K–3 students in Miami (Peiro & Fraser, 2009), 1081 students in 50 classes in Australia and 1879 students in

50 classes in Taiwan (Aldridge, Fraser, Taylor & Chen, 2000), 1083 Korean students in 24 classes (Kim, Fisher & Fraser, 1999) and 1864 South African students in 43 classes (Aldridge, Fraser & Sebela, 2004). As well, Johnson and McClure (2004) developed a shortened version of the CLES and validated it among students and teachers at the elementary-, middle- and high- school levels in Arizona.

Two recent studies in Asia involved the use of the CLES. In Singapore, Koh and Fraser (2014) used the CLES in evaluating a pedagogical model with a sample of 3207 secondary school students taught by preservice teachers. In Hong Kong, Kwan and Wong (2014) established positive associations between CLES scales and students' critical thinking ability among 967 secondary liberal studies students. While both studies reported support for the validity of the CLES, Koh and Fraser (2014) found that the pedagogical model had a positive impact in terms of students' perceptions of their classroom environments for all CLES scales.

2.3.6 What Is Happening In this Class? (WIHIC)

The WIHIC is the most-widely used learning environment questionnaire in the world today. It combines modified versions of salient scales from a range of existing questionnaires with additional scales that accommodate contemporary educational concerns (e.g. equity and constructivism). The original 90-item nine-scale version was refined by both statistical analysis of data from 355 junior high school science students and extensive interviewing of students about their views of their classroom environments in general, the wording and salience of individual items, and their questionnaire responses (Fraser, Fisher & McRobbie, 1996). Analysis of data from an Australian sample of 1081 students in 50 classes and a Taiwanese sample of 1879 students in 50 classes (Aldridge & Fraser, 2000; Aldridge, Fraser & Huang, 1999) led to a final form of the WIHIC containing seven eight-item scales (Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, Equity). Frequency response alternatives range from Almost Never to Very Often. Typical items are "I discuss ideas in class" (Involvement) and "I work with other students on projects in this class" (Cooperation).

Using a sample of 3980 high school students from Australia, Britain and Canada, confirmatory factor analysis supported the seven-scale a priori structure of the WIHIC (Dorman, 2003). All items loaded strongly on their own scale, although model fit indices revealed a degree of scale overlap. The factor structure was found to be consistent across countries, grade levels and genders. Overall, this study strongly supported the international applicability of the WIHIC as a valid measure of classroom psychosocial environment. Subsequently, in another study using multitrait–multimethod modelling, Dorman (2008) reported further evidence supporting the validity of actual and preferred forms of the WIHIC by using multitrait–multimethod modelling.

Table 2.2 lists 28 studies that have involved the use of the WIHIC in various countries and in various languages. The first 5 studies are example of cross-national research. The next 7 studies in Table 2.2 involved the use of the WIHIC in English in Singapore, India, Australia and South Africa. The 13^{th} and 14^{th} studies listed involved the use of the WIHIC, respectively, in the Korean language in Korea and in the Indonesian language in Indonesia. The next 2 studies involved the use of an

Arabic translation of the WIHIC in the United Arab Emirates. The last 12 entries in Table 2.2 are all studies that involved the use of the WIHIC in North America, including 1 study in Canada, 4 studies in California, 2 studies in New York and 5 studies in Florida. Although the four studies in Miami all involved the use of an English-language version of the WIHIC, it is noteworthy that three of them offered students the option of responding to a version of the WIHIC in either Spanish or English.

For each study involving the WIHIC in Table 2.2, details are provided not only of the country and language involved, but also the size of and nature of the sample. In this table, it also is noted that every study reported evidence to support the factorial validity and internal consistency reliability of the WIHIC. Finally, the last column of Table 2.2 identifies the unique contributions of each study. For example: Zandvliet and Fraser (2004, 2005) simultaneously investigated the physical and the psychosocial environment; Pickett and Fraser (2009) monitored the success of a mentoring program for beginning teachers in terms of changes in their school classroom environments; Robinson and Fraser's (2013) study of kindergarten students and their parents revealed that, relative to students, parents perceived a more favorable classroom environment but preferred a less favorable environment; and Helding and Fraser (2013) evaluated of the effectiveness of National Board Certified (NBC) teachers in terms of their students' perceptions of classroom environment.

Table 2.2 Details of 28 Studies Involving the Use of 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 Bahasa	567 students (Australia) and 594 students (Indonesia) in 18 secondary science classes	✓	Several attitude scales	Differences were found between countries and sexes
Zandvliet & Fraser (2004 2005)	Australia Canada	English	1404 students in 81 networked classes	✓	Satisfaction	Involved both physical (ergonomic) and psychosocial environments
Hanke & Fraser (2012)	USA Hong Kong	English	1309 grade 8 & 9 mathematics students	✓	Attitudes Efficacy	American students perceived the classroom environment more favorably, but Hong Kong students enjoyed mathematics more.
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
Peer & Fraser (in press)	Singapore	English	1081 primary students in 55 classes	✓	Attitudes	Identified sex, grade-level and stream differences
Koul & Fisher (2005)	India	English	1021 science students in 31 classes	✓	NA	Differences in classroom environment according to cultural background

Table 2.2 (continued)

Reference(s)	Country(ies)	Language(s)	Sample(s)	Factorial Validity & Reliability	Associations with Environment for:	Unique Contributions
Dorman (2008)	Australia	English	978 secondary school students	✓	NA	Multitrait–multimethod modelling validated actual and preferred forms
Velayutham & Aldridge (2013)	Australia	English	1360 grade 8–10 students in 5 schools	✓	Motivation Self-regulation	Identified classroom environment features that influence student motivation
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
Raaflaub & Fraser (2013)	Canada	English	1173 grade 7–12 students in 73 mathematics and science classes	✓	Attitudes	Learning environment perceptions were more positive for females and for science (relative to mathematics).
den Brok et al. (2006)	California, USA	English	665 middle-school science students in 11 schools	✓	NA	Girls perceived the environment more favourably.

Table 2 (continued)

Reference(s)	Country(ies)	Language(s)	Sample(s)	Factorial Validity & Reliability	Associations with Environment for:	Unique Contributions
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.
Taylor & Fraser (2013)	California USA	English	745 high-school students in 34 mathematics classes	✓	Attitudes Anxiety	Mathematics anxiety had two distinct dimensions that yielded different patterns of sex differences and anxiety–environment associations.
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
Cohn & Fraser (2013)	New York, USA	English	1097 grade 7 & 8 science students in 47 classes	✓	Attitudes Achievement	Use of Student Response Systems was evaluated using learning environment criteria
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 favourable environment but preferred a less favourable environment.

Table 2 (continued)

Reference(s)	Country(ies)	Language(s)	Sample(s)	Factorial Validity & Reliability	Associations with Environment for:	Unique Contributions
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.
Adamski, Fraser & Peiro (2013)	Florida, USA	Spanish	223 Hispanic grade 4–6 students	✓	Attitudes Achievement	Spanish translation Involved the subject of Spanish Student outcomes were related to both parental involvement and classroom environment.

Based on an updated version of Fraser (2012, 2014)

The WIHIC has been crossvalidated in many studies in numerous countries. For example, Table 2.2 shows that English-language versions of the WIHIC have been crossvalidated with 1077 grade 4–7 students in South Africa (Aldridge, Fraser & Ntuli, 2009), 1021 students in India (Koul & Fisher, 2005), 2310 grade 10 students in Singapore (Chionh & Fraser, 2009), 1404 students in Canada and Australia (Zandvliet & Fraser, 2004, 2005), 1434 middle-school students in New York (Wolf & Fraser, 2008) and 924 grade 8 and 10 students in Florida (Helding & Fraser, 2013). As well, the WIHIC has been translated into other languages and validated with 543 grade 8 students in Korea (Kim, Fisher & Fraser, 2000), 1879 junior high school students in Taiwan (Aldridge, Fraser & Huang, 1999), 763 college students in the United Arab Emirates (MacLeod & Fraser, 2010) and 594 secondary students in Indonesia (Fraser, Aldridge & Adolphe, 2010).

2.3.7 TROFLEI and COLES Based on WIHIC

The seven scales of the WIHIC have been included along with three new scales (namely, Differentiation, Computer Usage and Young Adult Ethos) to form the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI; Aldridge, Dorman & Fraser, 2004; Aldridge & Fraser, 2008). Based on an Australian sample of 2317 students in 166 classes, Aldridge and Fraser (2008) reported strong factorial validity and internal consistency reliability for the TROFLEI. Aldridge, Dorman and Fraser (2004) used multitrait–multimethod modelling 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 the 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 crossvalidating 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.

The Constructivist-Oriented Learning Environment Survey (COLES) incorporates numerous scales from the WIHIC into an instrument that is designed to provide feedback as a basis for reflection in teacher action research. In constructing the COLES, Aldridge, Fraser, Bell and Dorman (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 judgements 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. Interestingly, when analyses were performed separately for raw scores and Rasch scores, Aldridge et al. (2012) found that the differences between the validity results (e.g. reliability, discriminant validity and ability to differentiate between classrooms) were negligible. It is noteworthy that the COLES has been used successfully by teachers in action research aimed at improving their classroom environments (Aldridge et al., 2012).

2.3.8 Other Questionnaires

Working specifically in the Catholic school sector, Dorman, Fraser and McRobbie (1997) developed and validated the Catholic School Classroom Environment Questionnaire. Interestingly, use of this questionnaire revealed a difference between the rhetoric and the reality of classroom environments in Catholic schools (Dorman, Fraser & McRobbie, 1997).

Fisher and Waldrip (1997, 1999) developed the Cultural Learning Environment Questionnaire (CLEQ) to assess culturally-sensitive factors in students' learning environments (namely, Gender Equity, Collaboration, Deference, Competition, Teacher Authority, Modelling and Congruence). This questionnaire was used later in a 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).

The WEBLEI (Web-Based Learning Environment Instrument) was designed by Chang and Fisher (2003) to quantify Australian students' perceptions of their learning environments in a tertiary institution where the entire course was offered online. The WEBLEI measures students' perceptions of Access, Interaction, Response and Results. In another study (Chandra & Fisher, 2009), the course was offered in a blended environment to Australian students in a high school. Whereas courses in a university environment are generally delivered through sophisticated software, this course was delivered using a teacher-developed website. Therefore, the items in the WEBLEI were amended to suit the setting.

Although space does not permit a detailed discussion of other learning instruments, some of these other noteworthy questionnaires include:

- Distance Education Learning Environment Survey (DELES, Walker & Fraser, 2005)

- Distance and Open Learning Environment Survey (DOLES, Jegede, Fraser & Fisher, 1995)
- Constructivist Multimedia Learning Environment Survey (CMLES, Maor & Fraser, 2005).
- Place-based Learning And Constructivist Environment Survey (PLACES, Zandvliet, 2012, 2013).

2.4 TYPES OF PAST RESEARCH ON CLASSROOM LEARNING ENVIRONMENTS

Since the early 1960s, researchers have investigated the learning environment of the classroom and devised methods for evaluating the effectiveness of the interaction taking place in this environment and how it affects the learning of the students in that environment. As attempts are made to improve student outcomes in the classroom, often teachers use innovative techniques to bring about quantifiable results, classroom environment assessment tools can be effective for evaluating the effectiveness of innovative techniques. The subsections below identify several common lines of past learning environment research, namely, evaluation of educational innovations (Section 2.4.1), associations between classroom environment and student outcomes (Section 2.4.2), practical attempts to improve classroom environments (Section 2.4.3), links between educational environments (Section 2.4.4), cross-national studies (Section 2.4.5), and typologies of classroom environments Section 2.4.6). In contrast, in Section 2.5, past learning environment studies are grouped for review according to the country/region where the research was undertaken.

2.4.1 Evaluation of Educational Innovations

Classroom environment instruments have been used as a valuable source of process criteria in the evaluation of educational innovations. For example, in an early evaluation of the Australian Science Education Project, ASEP student perceived their classrooms as being more satisfying and individualised and having a better material environment relative to a comparison group (Fraser, 1979). In evaluating computer-assisted learning (Fraser & Teh, 1994), students using micro-PROLOG-based computer-assisted learning had much higher scores for achievement (3.5 standard deviations), attitudes (1.4 standard deviations), and classroom environment (1.0–1.9 standard deviations) than a comparison group.

Other examples of this application of learning environment assessments include evaluating the use of anthropometry activities in high-school science (Lightburn & Fraser, 2007) in Florida, inquiry-based computer-assisted learning in Australia (Maor & Fraser, 1996), outcomes-focused education in Australia (Aldridge & Fraser, 2008), National Board certification for teachers in Florida (Helding & Fraser, 2013), inquiry-based laboratory activities in New York (Wolf & Fraser, 2008), and computing courses for adults in Singapore (Khoo & Fraser, 2008). Some of these evaluation studies are discussed in more detail in Section 2.5 which reviews past learning environment research in several different countries.

Cohn and Fraser (2013) evaluated Student Response Systems (SRS) in science classes with a sample of 1097 grade 7 and 8 students in 47 classes in New York. Relative to non-SRS students, SRS students had considerably higher scores on learning environment scales (selected mainly from the WIHIC) and attitude and achievement measures.

The evaluation studies reviewed above all demonstrate the value of employing learning environment criteria in evaluating a wide range of educational programs among a wide range of samples from numerous countries. The success of these past studies motivated me to adopt a learning environment framework for my comparative evaluation of MAEA which involved comparing the learning environments of MAEA and non-MAEA students.

2.4.2 Associations Between Student Outcomes and Classroom Environment

The strongest tradition in past classroom environment research has involved investigation of associations between students' cognitive and affective learning outcomes and their perceptions of psychosocial characteristics of their classrooms. Relationships between outcome measures and classroom environment perceptions have been reported for a variety of cognitive and affective outcome measures, a variety of classroom environment instruments and a variety of samples (ranging across numerous countries and grade levels). For example, McRobbie and Fraser (1993) used the SLEI in an investigation of associations between student outcomes and classroom environment among 1594 senior high school chemistry students in 92 classes. Simple, multiple and canonical correlation analyses were conducted separately for two units of analysis (student scores and class means) and separately with and without control for general ability. Past research was replicated in that the nature of the science laboratory classroom environment accounted for appreciable proportions of the variance in both cognitive and affective outcomes beyond that attributable to general ability. Science educators wishing to enhance student outcomes in science laboratory settings are likely to find useful the result that both cognitive and attitude outcomes were enhanced in laboratory classes in which the laboratory activities were integrated with the work in non-laboratory classes.

Although many past learning environment studies have employed techniques such as multiple regression analysis, fewer have used multilevel analysis, which takes cognisance of the hierarchical nature of classroom setting (i.e., students within intact classes are more homogeneous than a random sample of students). When Wong, Young and Fraser (1997) used a sample of 1592 Grade 10 students in 56 chemistry classes in Singapore to investigate associations between three student attitude measures and a modified version of the SLEI, most of the statistically-significant results from the multiple regression analyses were replicated in the HLM analyses, as well as being consistent in direction. Another study employing HLM in investigating outcome-environment associations in Singapore was reported by Goh, Young and Fraser (1995) for a sample of 1512 grade 5 mathematics students.

Table 2.2 shows that the WIHIC has been used in numerous studies of outcome–environment associations conducted in various countries around the world. Furthermore, in the reviews of past research for specific geographical regions in Section 2.5, more details are provided for some studies of relationships between learning environment and student outcomes. The relevance of the studies reviewed in this section is that my study's third research question involved environment–attitude associations.

2.4.3 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) and the USA (Sinclair & Fraser, 2002).

Two studies in South Africa employed this approach with teachers who used teacher action research in attempts to improve their classroom learning environment. Aldridge, Fraser and Ntuli (2009) worked with 31 inservice teachers undertaking a distance-education program who administered a version of the WIHIC in the IsiZulu language to 1077 grade 4–7 learners. Aldridge, Fraser and Sebela (2004) worked with 29 mathematics teachers who administered an English version of the CLES to 1864 grade 4–9 learners.

In a recent study, teachers made use of the 11-scale COLES in action research that successfully led to improvements in their classroom learning environments (Aldridge, Fraser, Bell & Dorman, 2012). In addition to administering actual and preferred forms of the COLES as both pretest and posttests, reflective journals, written feedback, forum discussions and teacher interviews were used to provide feedback.

2.4.4 Investigation of Multiple Environments

Although most individual studies of educational environments in the past have tended to focus on a single environment, there is potential in simultaneously considering the links between, and the joint influence of, two or more environments. Several studies have investigated whether the nature of the school-level environment influences or transmits to what goes on in classrooms (i.e. the classroom-level environment). In South Africa, Aldridge, Fraser and Laugksch (2011) used a school environment instrument with 50 secondary-school science teachers from 50 different schools, together with a classroom environment questionnaire based on the WIHIC with the 2638 grade 8 students in the 50 classes of these 50 teachers. Although there emerged a small number of interesting specific relationships (e.g. schools encouraging teachers to be innovative was related to the extent to which students perceived more outcomes-based pedagogy in their classrooms), overall, the school environment did not have a strong influence on what happens in classrooms. When Dorman, Fraser and McRobbie (1997) administered a classroom environment instrument to 2211 students in 104 classes and a school environment instrument to the 208 teachers of these classes, only weak associations emerged between classroom environment and school environment. Although school rhetoric often would suggest that the school ethos would be transmitted to the classroom level, it appears that classrooms are somewhat insulated from the school as a whole.

Using secondary analysis of a large database from a Statewide Systemic Initiative (SSI) in the USA, Fraser and Kahle (2007) examined the effects of several types of environments on student outcomes. Over three years, nearly 7000 students in 392 middle-school science and mathematics classes in 200 different schools responded to a questionnaire that assesses class, home and peer environments as well as student attitudes. Students also completed an achievement measure. Rasch analyses allowed comparison 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 the peer group. Although all three environments accounted for statistically significant amounts of unique variance in student attitudes, 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 (Fraser & Kahle, 2007).

2.4.5 Cross-National Studies

Science education research which crosses national boundaries offers promise for generating new insights. 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 means in each country.

The largest differences in means between the two countries were for Involvement and Equity, 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 which 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 reults 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) and cross-national research in Hong Kong and the USA has been reported by Hanke and Fraser (2012).

2.4.6 Typologies of Classroom Environments

The creation and empirical investigation of typologies of classroom learning environments has been pursued in a handful of past studies. Using the CES in the USA among a sample of 200 junior-high and high-school classrooms, Moos (1978, 1979) identified five clusters that describe five learning environment orientations: control; innovation; affiliation; task completion; and competition. Using the QTI with samples of students in both The Netherlands and the USA led to the identification of eight distinct interpersonal profiles: directive; authoritative; tolerant–authoritative; tolerant; uncertain–tolerant; uncertain–aggressive; repressive; and drudging (Brekelmans, Levy & Rodriguez, 1993; Wubbels, Brekelmans, den Brok & van Tartwijk, 2006). Based on a large-scale administration of the QTI to 6148 grade 8–10 science students from 4 Australian states and their 283 teachers, Rickards, den Brok and Fisher (2005) reported that the 8 types found for Dutch and American teachers only partly applied to the Australian context. Whereas some profiles were less common in Australia, others were more common. Two new types (namely, flexible and cooperative–supportive) were unique to the Australian sample.

Working in Turkey with a Turkish translation of the WIHIC, den Brok, Telli, Cakiroglu, Taconis and Tekkaya (2010) created learning environment profiles for a sample of 1474 high-school biology students in 52 classes. The six distinct classroom profiles that emerged were: self-directed learning; task-orientated cooperative learning; mainstream; task-orientated individualized; low-effective learning; and high-effective learning. The most common profile was the mainstream classroom for which all WIHIC scales had medium–high scores. Based on sample of 4146 Australian students from 286 grade 8–13 classes, Dorman, Aldridge and Fraser (2006) used the ten-scale TROFLEI to develop a classroom typology with five relatively homogeneous groups of classes: exemplary; safe and conservative; non-technological teacher-centred; contested technological; and contested non-technological. The authors recommended more frequent use of cluster analysis in order to achieve greater parsimony in analysing classroom environment data.

2.5 PAST LEARNING ENVIRONMENTS RESEARCH IN DIFFERENT COUNTRIES

In this section, past learning research is further reviewed using a different organizational structure, namely, grouping studies according to the country in which data were collected. Section 2.5.1 is devoted to learning environments research in Asia, Section 2.5.2 reviews past research in North America, and Section 2.5.3 considers past research on classroom environments in African and Arab countries. Because very little past learning environment research has specifically involved samples of African-American students, I considered it important to have a thorough knowledge of past research from many different geographical locations.

2.5.1 Learning Environments Research in Asia

Collaboration between Korean and Australian science education researchers involved the translation, validation and use of the CLES (Kim, Fisher & Fraser, 1999) with 1083 science students in 12 schools, as well as the use of WIHIC and QTI (Kim, Fisher & Fraser, 2000) with a sample of 543 Grade 8 science students in the same 12 schools. This study paved the way for later learning environment research in Korea by crossvalidating a Korean-language version of three well-established questionnaires, as well as replicating past studies of associations between student outcomes and the nature of Korean science classroom environments.

Kim's research in Korea was followed up by Lee. In addition to using and crossvalidating a Korean-language version of the QTI (Lee, Fraser & Fisher, 2003), Lee also translated and validated a Korean-language version of the SLEI (Fraser & Lee, 2009) with a sample of 440 Grade 10 and 11 students in 13 classes. As well as replicating past findings of outcome–environment associations, interesting differences were found between the learning environment perceptions of science students in three different streams (science-independent, science-oriented and humanities). Teacher–student interactions in Korean senior high school science classrooms reflected the general image of the youth–elder relationship in society, as well as the senior high school's unique nature – portraying a scene of 'directing teachers and obeying students'.

While working in Brunei Darussalam, Scott undertook the translation and validation of a Malay version of the QTI with 3104 science students in 136 classrooms. Statistical analyses revealed that this Malay version of the QTI for these Malay-speaking primary school students in Brunei was valid and reliable. When associations between students' perceptions of their teachers' interpersonal behaviours and their end-of-year results on an external science examination were investigated, achievement was correlated positively with students' perceptions of cooperative behaviors and negatively with submissive behaviours (den Brok, Fisher & Scott, 2005; Scott & Fisher, 2004).

In contrast to Scott's use of a Malay-language version of a learning environment questionnaire in Brunei, a modified English-language version of the My Class Inventory (MCI) was used with 1565 students from 81 classes. As well as crossvalidating the MCI for use in Brunei, Majeed, Fraser and Aldridge (2002) reported sex differences in students' perceptions, as well as associations between student satisfaction and positive classroom environments.

Koul and Fisher crossvalidated English versions of the QTI and WIHIC in Jammu, India, among 1021 students from 31 classes. It was found that Kashmiri students perceived their classroom environments more positively than did students from other cultural groups (Koul & Fisher, 2005).

Indonesian educators were involved in the translation and crossvalidation of questionnaires in the Indonesian language and the beginning of traditions of learning environment research in that country. Margianti undertook research involving an Indonesian version of the WIHIC with a large sample of 2498 university students in 50 classes (Margianti, Aldridge & Fraser, 2004). Student achievement was better when lecturers emphasized classroom involvement and equity, and attitudes were more positive when there was more teacher support, involvement, task orientation and equity. Another study in Indonesia involved the use of the WIHIC among 1188 lower-secondary students in 72 science classes in Kalimantan Selatan (Wahyudi & Treagust, 2004). As well as crossvalidating the WIHIC and reporting significant differences between actual and preferred classroom environments, these researchers identified differences in classroom environments according to locality. Students in rural schools held less favourable perceptions than students in urban and suburban schools for all WIHIC scales. Students in urban and suburban schools generally perceived their classroom environments similarly, with the exception that students in urban schools perceived more cooperation and less teacher support than did student in suburban schools. Also, in Indonesia, Fraser, Aldridge and Soerjaningsih (2010) validated an Indonesian version of the QTI with 422 university students.

Singaporean educational researchers have made numerous and important contributions to the field of learning environments. Using a locally-developed questionnaire that drew ideas from existing instruments, Teh and Fraser (1994, 1995a, 1995b) used learning environment criteria in the evaluation of computer-assisted learning among a sample of 671 secondary students in 24 classes. Khoo and Fraser (2008) crossvalidated an adapted version of the WIHIC with a sample of 250 working adults, who reported higher satisfaction in classes with more teacher support, involvement and task orientation.

Working specifically with final-year chemistry students (1592 students in 28 classes), Wong and Fraser (1996) reported the first major study in Singapore into associations between students' attitudes to science and the perceived classroom learning environment. For this study, the original SLEI was modified to form the Chemistry Laboratory Environment Inventory (CLEI). Strong and statistically significant attitude–environment associations were confirmed through multilevel analysis (Wong, Young & Fraser, 1997). In a later study involving 497 chemistry students responding to both the CLEI and the QTI, Quek, Wong and Fraser (2005a, 2005b) not only replicated the existence of attitude–environment associations, but also reported significant differences in classroom environment perceptions according to the student's sex and stream (i.e. gifted vs non-gifted).

Other large-sample collaborative studies in Singapore have involved the adaptation, validation and application of well-known learning environment questionnaires. For example, relationships between psychosocial climate and student achievement and attitudes were established for 1512 primary-school students using both multiple regression analysis (Goh & Fraser, 1998) and multilevel analysis (Goh, Young & Fraser, 1995). Both the MCI and QTI were adapted and used. When Chionh and Fraser (2009) used the WIHIC among 2310 Grade 10 students in 75 classes, they found large differences between actual and preferred learning environment scores. Also better examination scores were found in classrooms with more student cohesiveness, whereas self-esteem and attitudes were more favorable in classrooms with more teacher support, task orientation and equity. Peer and Fraser (in press) reported sex, grade-level and stream differences when they administered the WIHIC to 1081 primary students in 55 classes.

2.5.2 Learning Environments Research in North America

Numerous learning environment questionnaires originally developed in Australia have been modified and crossvalidated with large samples of students in the USA. For example, the WIHIC has been crossvalidated with 655 middle-school students in California (den Brok, Fisher, Rickards & Bull, 2006), 525 university students in California (Martin-Dunlop & Fraser, 2008), 573 primary-school students in Florida (Pickett & Fraser, 2009) and 1434 middle-school students in New York

(Wolf & Fraser, 2008). The SLEI has been crossvalidated with 761 high-school biology student in Florida (Lightburn & Fraser, 2007) and the CLES has been crossvalidated with 1079 students in 59 classes in North Texas (Nix, Fraser & Ledbetter, 2005) and 739 Grades K–3 students in Florida (Peiro & Fraser, 2009). Peiro's research with the CLES also involved its translation into the Spanish language.

As well as replicating findings from past research concerning empirical links between positive classroom environments and improved student outcomes, the studies referred to above provide good examples of the use of learning environment scales as criteria of effectiveness in the evaluation of educational programs and teaching methods. For example, these studies included evaluations of the use of anthropometric activities (Lightburn & Fraser, 2007), an innovative science course for prospective primary teachers (Martin-Dunlop & Fraser, 2008), an innovative teacher development program (Nix & Fraser, 2010; Nix, Fraser & Ledbetter, 2005), an instructional intervention for early childhood children based on constructivist principles (Peiro & Fraser, 2009) and inquiry-based activities for middle-school science students (Wolf & Fraser, 2008).

Although the evaluation of teacher professional development programs often involves surveying participant teachers' opinions and satisfaction related to various aspects of a program, Pickett and Fraser (2009) argue that the litmus test of the success of any professional development program is the extent of changes in teaching behaviours and ultimately student outcomes in the participating teachers' school classrooms. Their evaluation of a two-year mentoring program in science for beginning elementary-school teachers is unique in that it drew on the field of learning environments in evaluating this program in terms of participants' classroom teaching behavior as assessed by their school students' perceptions of their classroom learning environments. As well, students' attitudes to and achievement in science were assessed. Changes over a school year were monitored for a sample of seven beginning Grade 3–5 teachers in southeast USA and their 573 elementary school students. Data analyses supported the sound factorial validity of the WIHIC, while the use of MANOVA and effect sizes supported the efficacy of the mentoring program in terms of some improvements over time in the classroom learning environment and students' attitudes and achievement (Pickett & Fraser, 2009).

For the first time in any study, parents' perceptions were utilised in conjunction with students' perceptions in investigating science classroom learning environment among grade 4 and 5 science students in south Florida (Allen & Fraser, 2007). The WIHIC was modified for young students and their parents and administered to 520 students and 120 parents. Both students and parents preferred a more positive classroom environment than the one perceived to be actually present, but effect sizes for actual–preferred differences were appreciably larger for parents than for students. With a sample of 78 parents and their 172 kindergarten science students in Miami, Robinson and Fraser (2013) used a simplified Spanish version of the WIHIC to reveal that, relative to students, parents perceived a more favorable classroom environment but preferred a less favorable environment.

Unique research in Canada focused simultaneously on the psychosocial and physical environments of networked classrooms (Zandvliet & Fraser, 2004, 2005). Whereas the psychosocial environment was assessed with the WIHIC, ergonomic evaluations were made of the physical environment (e.g. workspace and visual environments). For a sample of 1404 students (which included Australian students as well as Canadians), classroom psychosocial environment was significantly and directly associated with students' satisfaction with their learning, but no direct associations were found between student satisfaction and measures of the physical classroom environment. However statistically significant associations emerged between physical and psychosocial learning environment variables in classrooms using new information technologies. These associations suggested a model of educational productivity for learning environments in technology-rich classrooms.

2.5.3 Learning Environments Research in African and Arab Countries

Research on classroom learning environments has slowly begun to take root in Africa. Nigerian researchers developed and used questionnaires for investigating learning environments in science laboratory classes (Fraser, Okebukola & Jegede, 1992) and the role of sociocultural beliefs in hindering learning in science classroom environments (Jegede, Fraser & Okebukola, 1994). Also in Nigeria, use of scales from the CLES and ICEQ in a study of 1175 agricultural science students in 50 classes from 20 schools (Idiris & Fraser, 1997) revealed low levels of classroom student-centredness and student negotiation.

In South Africa, a national curriculum reform involving outcomes-based education stimulated the development and use of new learning environment instruments for monitoring the development of outcomes-based learning environments. At the classroom level, Aldridge, Laugksch, Seopa and Fraser (2006) developed the OBLEQ (Outcomes-Based Learning Environment Questionnaire) in the North Soto language and validated it with a sample of 2638 Grade 8 science students from 50 schools in the Limpopo Province. At the school level, Aldridge, Laugksch and Fraser (2006) developed a South African version of the School-Level Environment Questionnaire and validated it with a sample of 403 teachers. The study revealed differences between teachers' perceptions of actual and preferred school environment, and also that teachers who had been involved in outcomes-based education perceived their school environments differently from teachers who had not been involved.

In another study in South Africa, Aldridge, Fraser and Sebela (2004) adapted the English version of the CLES for use among teachers and their 1864 students in 43 classes who were attempting to change classroom environments to a more constructivist orientation. Not only did their study yield a validated and widely-applicable questionnaire for future use, but also it involved case studies of teachers' successful and not-so-successful attempts to change their classroom environments during a 12-week intervention period. Also in South Africa, Aldridge, Fraser and Ntuli (2009) investigated 31 inservice teachers who were undertaking a distance-education program and who administered a primary-school version of the WIHIC in the IsiZulu language to 1077 grade 4–7 learners in the KwaZulu-Natal province. Different teachers were able to use feedback from the WIHIC with varying degrees of success in their attempts to improve their classroom environments.

Apparently, learning environment research has been virtually nonexistent in the Arabic-speaking world, perhaps partly because of the unavailability of any validated questionnaires in the Arabic language. MacLeod and Fraser (2010) pioneered the painstaking translation and comprehensive validation of an Arabic version of the WIHIC with a sample of 763 college students in 82 classes in the United Arab Emirates. As well as providing a useful and valid learning environment questionnaire for future use by researchers and practitioners in Arabic-speaking countries, MacLeod and Fraser reported that students would prefer their classroom environments to be more positive for all dimensions assessed. In another study involving a translation of WIHIC into Arabic, Afari and colleagues reported that the use of mathematics games promoted positive classroom environments among a sample of 352 college students in 33 classes (Afari, Aldridge, Fraser & Khine, 2013). Most recently, Hasan and Fraser (in press) used a modified version of the CUCEI in the Arabic language in an investigation of the effectiveness of teaching strategies that engage college students who had experienced childhood difficulties in learning mathematics in the UAE.

2.6 STUDENT ATTITUDES TO SCIENCE

Whereas Sections 2.2–2.5 above reviewed literature from the field of learning environments, this section is devoted to literature concerning student attitudes, which also were used as criteria of effectiveness in my evaluation of MAEA interactive science programs.

The concept of attitude, its definition and its measurement have been widely explored in books such as Eiser (1984) and Mueller (1986). According to Mueller (1986), because attitudes cannot be observed or measured directly, their existence must be inferred from their consequences. Given that an attitude is a non-observable psychological construct that can only be deduced from the behavior manifested, it is not surprising that there is no unanimous agreement amongst social scientists about how to define the term attitude. Reid's (2006) definition of attitudes involves three components, namely, cognitive (knowledge of the object, belief or ideas), affective (feelings regarding the object, such as like or dislike) and behavioral (the tendency towards an action or objective). Kind, Jones and Barmby (2007, p. 873) provide a definition based on these components of attitudes as "the feelings that a person has about an object [evaluative attitudes are always towards something often called an attitude object] based on their beliefs about that object".

According to Breckler and Wiggins (1989), attitudes are composed from various forms of judgments and develop on an ABC model (affect, behavioral change and cognition). The affective response is a physiological response that expresses an individual's preference for an entity. The behavioral intention is a verbal indication of the intention of an individual. The cognitive component involves a person's knowledge/belief about an attitude object. Most attitudes in individuals are a result of observational learning from their environment.

Over the years, various methods have been developed to measure attitudes, such as Likert scaling, Thurstone scaling, Guttman scaling and the semantic differential technique. In measuring the attitude of a respondent using the Likert scaling technique, the researcher locates the respondent's position on a continuum ranging from the extreme end of positive to that of negative. Responses to given statements about an attitudinal object on a five-point continuum (e.g., strongly agree, agree, uncertain, disagree and strongly disagree) are tallied.

According to Hannula (2002), attitudes involve the emotions aroused by a situation, the emotions associated with a stimulus, expected consequences, and the relationship of a situation to personal values. Various instruments have been developed to assess students' attitudes to mathematics (Sandman, 1980), computers (Miyashita & Knezek, 1992) and science (Fraser, 1981a), as well as their anxiety when learning various subjects (Taylor & Fraser, 2013). In science, activity-based instruction has been found to promote positive student attitudes (Kyle, Bonstetter, Gadsden & Shymansky, 1988). Links between students' attitudes and the nature of their classroom learning environments have been reported by numerous researchers (Fraser, 2012, 2014; McRobbie & Fraser, 1993) and in numerous studies around the world that are listed in Table 2.2.

In science education, the measurement and investigation of students' attitudes has 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 widely-cited work of Munby (1983, 1997) and Osborne, Simons and Collins (2003) in identifying numerous important, well-known 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 the 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 validity and 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 summed up the TOSRA as "an exceptionally well developed scale" (Munby, 1983, p. 314).

TOSRA measures seven distinct science-related attitudes among secondary school students: Social Implications of Science; Normality of Scientists; Attitude to Scientific Inquiry; Adoption of Scientific Attitudes; Enjoyment of Science Lessons; Leisure Interest in Science; and Career Interest in Science (Fraser, 1978, 1981a). Table 2.3 lists the name of each TOSRA scale and its classification according to Klopfer's (1971) scheme. Each scale contains 10 items, making a total of 70 items for the whole instrument. The response scale is a five-point Likert scale and has response categories ranging from Strongly Agree to Strongly Disagree. TOSRA probably is still the most widely-used attitude instrument in science education research today.

Table 2.3 Name and Classification of Each Scale in TOSRA

TOSRA Scale Name		Klopfer (1971) Classification
Social Implications of Science Normality of Scientists	H.1:	Manifestation of favourable attitudes towards science and scientist
Attitude to Scientific Inquiry	H.2:	Acceptance of scientific inquiry as a way of thought
Adoption of Scientific Attitudes	H.3:	Adoption of 'scientific attitudes'
Enjoyment of Science Lessons	H.4:	Enjoyment of science learning experiences
Leisure Interest in Science	H.5:	Development of interest in science and science related activities
Career Interest in Science	H.6:	Development of interest in careers in science and science related fields

In addition to studies that have investigated the validity of the TOSRA (Kalili, 1987; Schibeci & McGaw, 1981), the TOSRA has been used to evaluate innovations (Lott, 2002), to compare the attitudes of different groups of students (White & Richardson, 1993; Joyce & Farenga, 1999), and to explore associations between the learning environment and students' attitudes (Fraser, Aldridge & Adolphe, 2010; Fraser & Butts, 1982; Fraser & Fisher, 1982; Wong & Fraser, 1996). For the purposes of my study, two of the seven TOSRA scales were selected as being the most salient: Attitude to Scientific Inquiry and Enjoyment of Science Lessons.

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 (2007) research in California, Spinner and Fraser's (2005) study in Florida and Chapman's (2012) study in Georgia. In Singapore, TOSRA was modified to form the Test of Chemistry Related Attitudes (TOCRA) and used with 1592 final-year chemistry students (Wong & Fraser, 1996) and 497 tenth-grade chemistry students (Quek, Wong &

Fraser, 2005b). 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 & Peiro (2013) modified TOSRA to form the Test of Spanish Related Attitudes and used it with 223 grade 4–6 students learning Spanish. In China, Liu and Fraser (2013) modified the TOSRA for use in English classes, translated it into the Chinese language, and crossvalidated it with 1235 high-school students.

2.7 SUMMARY

Because my study drew upon and contributed to the field of learning environments, this chapter's main purpose was to provide a comprehensive review of international literature in this field. As well, because students' attitudes to science were assessed and investigated in my study, a review of literature on attitudes also was included in this chapter.

A brief historical perspective was provided on the field of learning environments, starting with the seminal foundations laid by Walberg and Moos in the late 1960s, and tracing developments to the present day. Because questionnaires have played such a central role in research in learning environments, a review was provided of historically-significant questionnaires and the most-frequently used instruments today, such as the What Is Happening In this Class? (WIHIC), Questionnaire on Teacher Interaction (QTI), Science Laboratory Environment Inventory (SLEI), and Constructivist Learning Environment Survey (CLES).

Because the WIHIC was chosen for my study, past research using the WIHIC around the world for many research purposes was a particular focus of this chapter. In particular, Table 2.2 summarizes the details of 28 studies involving the WIHIC in numerous languages and countries.

Past research on learning environments was reviewed using two methods of organization. First, in Section 2.4, past studies were grouped into five themes: evaluation of educational innovations; associations between student outcomes and classroom environment; improving classroom environments; investigations of multiple environments; cross-national studies; and typologies of classroom environments. Second, in Section 2.5, I reviewed past studies according to the countries in which they were conducted: Asia; North America; and African and Arab countries.

Finally, a section of Chapter 2 was devoted to literature about the conceptualization and assessment of attitudes. Particular attention was devoted to the Test of Science Related Attitudes (TOSRA) from which I drew scales for inclusion in my study.

Chapter 3

RESEARCH METHODS

3.1 INTRODUCTION AND OVERVIEW

For my research involving the relative effectiveness of MAEA's interactive science programs in terms of African-American students' attitudes and perceptions of classroom learning environment, I chose five scales from the What Is Happening In this Class? (WIHIC) (namely, Cooperation, Teacher Support, Involvement, Investigation and Task Orientation) to assess students' perceptions of their science classroom learning environments. To assess students' attitudes toward science, I used two scales from the Test of Science Related Attitudes (TOSRA): Attitudes to Scientific Inquiry and Enjoyment of Science Lessons.

This chapter describes the research design and methods used in my study. My design involved pretest and posttest administrations of the WIHIC and TOSRA to the 85 8th grade students at the MAEA intervention school and 183 8th grade students at the two comparison schools. The discussion in this chapter is organized under several headings:

Section 3.2 Sample and science instruction

Section 3.3 Description of WIHIC and TOSRA

Section 3.4 Methods of data analysis

Section 3.5 Chapter summary.

3.2 SAMPLE AND SCIENCE INSTRUCTION

My research involved administering questionnaires for assessing the classroom environment and students' attitudes to science to 8th grade students in the three schools (one MAEA school and two comparison schools) located in the Columbus City School District in Ohio. In Section 1.4.2 of Chapter 1, I provided contextual information about this school district and the particular neighborhoods where my study's schools were situated.

The comparison schools provided 139 and 44 grade 8 students, respectively, making a total of 183 students. At the MAEA intervention school, there were 85 grade 8 students who participated. Therefore the total sample consisted of 268 students. The bottom of Table 3.1 summarizes the sample sizes for the schools in my study and for the entire grade 8 population in the Columbus City School District at the time of my study (www.columbus.k12.oh.us).

Table 3.1 Three Background Characteristics of Grade 8 Students for MAEA School, Comparison Schools, and Whole Columbus City School District

Background Characteristic	MAEA School	Comparison School 1	Comparison School 2	Columbus City Schools
Economically disadvantaged (%)	99.6	99.4	99.0	98.1
African-American (%)	79	82	76	62
Limited English Proficient (%)	13	12	8	9
Sample Size	85	139	44	3350

Table 3.1 compares students in the three schools in my study with each other and with the Columbus City School District as a whole on three important

background characteristics: economic disadvantage, proportion of African-Americans, and proportion of students with limited English proficiency.

In the Columbus City School District, economic disadvantage is defined in terms of family income based on federal guidelines. Students are considered to be economically disadvantaged if their family income is low enough to qualify them to receive either free or reduced-priced lunch from the District. To ascertain a student's ethnicity in this District (as in many school districts throughout the USA), parents are asked to select an ethnicity from a set of alternatives at the time of the student's initial enrolment.

Table 3.1 shows that nearly all 8th grade students in my study's schools and the district as a whole are economically disadvantaged (at least 98%) and that the proportion of African-American students is high in the MAEA school (79%) and the comparison schools (82% and 76%), but lower for the district overall (62%). The proportion of Limited English Proficient students ranges from 8% to 13% for the three schools in my research and is 9% for the district as a whole.

Overall Table 3.1 suggests reasonable comparability between the three schools in my study on these three important demographic characteristics. This provides confidence concerning the internal validity of my study for comparison of the MAEA school with the control schools in terms of classroom environment and student attitudes. Although the students in the schools in my study are quite similar to the whole school district with respect to economic disadvantage and English proficiency, my study's schools have a higher proportion of African-American students (76% to 82%) compared with all of the Columbus City School District

(62%). Therefore, caution is needed when attempting to generalize any findings from my study to the whole school district.

The three schools in my study each had two grade 8 science teachers who each taught several classes. Although all grade 8 students in these schools were intended for inclusion in my study, the final sample size was smaller than this population because of attrition. Some students didn't gain parental approval to participate, some students were absent at the time of pretesting and/or posttesting, and many students changed schools between the time of pretesting and posttesting. (My research design necessitated the exclusion of any student who did not have a matched pretest and the posttest questionnaire.)

The duration of my study was one school year, with pretesting taking place in September and posttesting in May. Informal interviews with teachers confirmed that, in all three schools, the amount of hands-on inquiry-based science teaching was quite limited. However, I visited the experimental school over the duration of the study to provide some inquiry-based science experiences.

All grade 8 students in each school had a 47-minute science class on each of the five days of the week with their usual teacher. In addition, I visited the MAEA school once a month to provide one additional 47-minute science lesson to all grade 8 students at this school. Usually, I met with each science class individually, but occasionally two classes were combined in the one classroom. At the beginning of the school year, I provided an interactive Science Spectacular experience to all students at the experimental school at a whole-school assembly. (For the two comparison schools, I provided a similar whole-school assembly Science Spectacular experience in May after the conclusion of the study).

After initially motivating students through the Science Spectacular, I provided hands-on science activities in the classrooms of the 8th grade students at the MAEA school once per month for the remainder of the school year. The content for each of these programs was given to me by the science teachers at the beginning of each month prior to my visit. There were two primary strands of content that followed the teachers' lesson plans, scope and sequence. I planned inquiry-based activities that were relevant to these content strands, and I introduced students to African-American role models of scientists and inventors. In an attempt to multiply the effects of the hands-on science with the students, the two science teachers at the experimental school received professional development directly from me, including suggestions about additional hands-on activities that they could provide to their students in between my visits. However, these teachers seldom attempted to implement any of the hands-on activities that I had suggested. Further information about MAEA's interactive science programs can be found in Section 1.2 of Chapter 1 and are available from websites (www.maeasciencecenter.org and www.Interactivescienceprograms.org).

Ethical issues were carefully considered prior to commencing my research. Approval for the study was obtained from both the Curtin University Human Research Ethics Committee (HREC) and the Curriculum Quality Control Council (CQCC) of Columbus Public Schools. The reason why approval was needed from the CQCC is that my intervention constituted an enhancement to the grade 8 science curriculum. I particularly paid attention to Leedy and Ormerod's (2012) four main categories of ethical considerations: protection from harm, informed consent, right to privacy, and honesty with professional colleagues.

Protection from harm was assured in that my research only involved students in responding to a 30-minute questionnaire. Informed consent followed protocols required by Curtin University's HREC: my research proceeded only after consent had been obtained from the parents/guardians of all participating students. Right to privacy was accommodated by using anonymous reporting and by making arrangements to store data electronically at Curtin University for five years. Honesty with professional colleagues involved following Curtin HREC protocol of providing participating teachers with a written information sheet about the study and allowing them the opportunity to ask me questions of clarification.

3.3 DESCRIPTION OF WIHIC AND TOSRA

Because the WIHIC and TOSRA were so central to the design of my study, further information about each instrument is provided in this section. Previously literature relevant to these questionnaires was reviewed in Chapter 2 in Section 2.3.6 for the WIHIC and in Section 2.6 for TOSRA. Below, the WIHIC is discussed in Section 3.3.1, whereas information about TOSRA is provided in Section 3.3.2.

3.3.1 What Is Happening In this Class? (WIHIC)

As noted in Chapter 2, the WIHIC is the most-widely used learning environment questionnaire in the world today. Its development involved combining modified versions of salient scales from a range of existing questionnaires with additional scales that accommodate contemporary educational concerns. The

WIHIC's authors originally designed a 90-item nine-scale version which was refined based on both statistical analysis of data from 355 junior high school science students and interviewing of students (Fraser, Fisher & McRobbie, 1996). Later, analysis of data from an Australian sample of 1081 students in 50 classes and a Taiwanese sample of 1879 students in 50 classes (Aldridge & Fraser, 2000; Aldridge, Fraser & Huang, 1999) led to a final form of the WIHIC containing seven eight-item scales (Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, Equity), with frequency response alternatives of Almost Never, Seldom, Sometimes, Often and Very Often.

Some descriptive information is provided about the WIHIC's seven scales in Table 3.1. This table clarifies the meaning of and WIHIC scale by providing a scale description and a sample item. Furthermore, Table 3.1 provides the classification of each WIHIC scale according to Moos' (1974) three basic types of dimensions for classifying the individual characteristics of any human environment. These are Relationship dimensions (which identify the nature and intensity of personal relationships within the environment and assess the extent to which people are involved in the environment and support and help each other), Personal Development dimensions (which assess basic directions along which personal growth and enhancement tend to occur), and System Maintenance and System Change dimensions (which involve the extent to which the environment is orderly, clear in expectations, maintains control and is responsive to change).

Table 2.2 in Chapter 2 listed 28 studies that have crossvalidated the WIHIC in various countries and in various languages. The first 5 studies are examples of cross-national validations. The next 7 studies in Table 2.2 involved the validation of the WIHIC in English in Singapore, India, Australia and South Africa. The 13th and 14th studies listed involved validation of the WIHIC, respectively, in the Korean language in Korea and in the Indonesian language in Indonesia. The next 2 studies involved the validation of Arabic translations of the WIHIC in the United Arab Emirates. The last 12 entries in Table 2.2 are all studies that involved the validation of the WIHIC in the USA, including 4 studies in California, 2 studies in New York and 5 studies in Florida.

Table 3.2 Moos Classification, Scale Description and Sample Item for each WIHIC Scale

Scale		Description	Sample Item
		The extent to which …	
Student Cohesiveness	R	students know, help and are supportive of one another.	Students in this class like me.
Teacher Support	R	the teacher helps, befriends, trusts and is interested in students.	The teacher is interested in my problems.
Involvement	R	students have attentive interest, participate in discussions, do additional work and enjoy the class.	I explain my ideas to other students.
Investigation	P	emphasis is placed on the skills and processes of inquiry and their use in problem solving and investigation.	I find out answers to questions by doing investigations.
Task Orientation	P	it is important to complete activities planned and to stay on the subject matter.	I know the goals for this class.
Cooperation	P	students cooperate rather than compete with one another on learning tasks.	I work with other students on projects in this class.
Equity	S	students are treated by the teacher.	The teacher gives as much attention to my questions as to other students' questions.

The response alternatives for each item are Almost Never, Seldom, Sometimes, Often and Almost Always
R: Relationship, P: Personal Development; S: System Maintenance and Change
Based on Aldridge & Fraser (2008)

In terms of sample sizes, Table 2.2 shows that English-language versions of the WIHIC have been crossvalidated with 1077 grade 4–7 students in South Africa (Aldridge, Fraser & Ntuli, 2009), 1021 students in India (Koul & Fisher, 2005), 2310 grade 10 students in Singapore (Chionh & Fraser, 2009), 1404 students in Canada and Australia (Zandvliet & Fraser, 2004, 2005), 1434 middle-school students in New York (Wolf & Fraser, 2008) and 924 grade 8 and 10 students in Florida (Helding & Fraser, 2013). As well, the WIHIC has been translated into other languages and validated with 543 grade 8 students in Korea (Kim, Fisher & Fraser, 2000), 1879 junior high school students in Taiwan (Aldridge, Fraser & Huang, 1999), 763 college students in the United Arab Emirates (MacLeod & Fraser, 2010) and 594 secondary students in Indonesia (Fraser, Aldridge & Adolphe, 2010).

For a sample of 3980 high school students from Australia, Britain and Canada, Dorman (2003) used confirmatory factor analysis to support the seven-scale structure of the WIHIC. All items loaded strongly on their own scale, although there was a degree of scale overlap. The factor structure was the same for different countries, grade levels and student genders. Overall, this study strongly supported the international validity of the WIHIC. In a later study using multitrait–multimethod modelling, Dorman (2008) used both the actual and preferred forms of the WIHIC with a sample of 978 secondary-school students from Australia. Separate confirmatory factor analyses for the actual and preferred forms supported the seven-scale a prior structure. The WIHIC's construct validity was supported by the use of multitrait–multimethod modeling with the seven scales as traits and the two forms of the instrument as methods.

3.3.2 Test of Science Related Attitudes (TOSRA)

As noted in Chapter 2, the widely-used Test of Science-Related Attitudes (TOSRA, Fraser, 1981a) was used in my study because it overcomes most of the problems identified by Kind, Jones and Barmby (2007) and Munby (1997). First, the TOSRA clearly defines each construct 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. Second, the TOSRA does not combine conceptually-different constructs to form one scale. Third, past studies with TOSRA have provided strong evidence of its psychometric quality. Fourth, each scale of the TOSRA has demonstrated unidimensionality and independence in past studies through factor analysis. After investigating the adequacy of dozens of attitude instruments, Munby (1983) concluded that TOSRA was exceptionally well-designed.

TOSRA measures seven distinct science-related attitudes among secondary school students: Social Implications of Science; Normality of Scientists; Attitude to Scientific Inquiry; Adoption of Scientific Attitudes; Enjoyment of Science Lessons; Leisure Interest in Science; and Career Interest in Science (Fraser, 1978, 1981a). Each scale contains 10 items, making a total of 70 items for the whole instrument. The response scale is a five-point Likert scale ranging from Strongly Agree to Strongly Disagree. TOSRA probably is still the most widely-used attitude instrument in science education research today. Table 2.3 in Chapter 2 lists the name of each TOSRA scale and its classification according to Klopfer's (1971) scheme.

Extensive research has confirmed the validity of the TOSRA (Kalili, 1987; Schibeci & McGaw, 1981). It has been used to evaluate innovations (Lott, 2002), compare the attitudes of different groups of students (White & Richardson, 1993; Joyce & Farenga, 1999), and explore associations between the learning environment and students' attitudes (Fraser, Aldridge & Adolphe, 2010; Fraser & Butts, 1982; Fraser & Fisher, 1982; Wong & Fraser, 1996). For my study, two of TOSRA's scales selected were: Attitude to Scientific Inquiry and Enjoyment of Science Lessons.

Although TOSRA originally was developed to assess students' attitudes specifically to the subject of science, it has been adapted for other subjects. Several researchers in the USA changed the word 'science' to 'mathematics' to form the Test of Mathematics Related Attitudes (TOMRA) (e.g. Ogbuehi & Fraser, 2007; Spinner & Fraser, 2005). In Singapore, TOSRA was modified to form the Test of Chemistry Related Attitudes (TOCRA) and validated with 1592 final-year chemistry students (Wong & Fraser, 1996) and 497 tenth-grade chemistry students (Quek, Wong & Fraser, 2005b). 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 & Peiro (2013) modified TOSRA to form the Test of Spanish Related Attitudes and used it with 223 grade 4–6 students learning Spanish. In China, Liu and Fraser (2013) used part of TOSRA in English classes with a sample of 1235 high-school students.

3.4 METHODS OF DATA ANALYSIS

Because my study involved three research questions based on data from WIHIC and TOSRA scales, this section is devoted to identifying and describing the methods of statistical analysis used for answering each research question. Section 3.4.1 is devoted to the methods of analysis that I chose for answering my first research question involving validating the WIHIC and TOSRA scales with my sample. Section 3.4.2 considers the methods of statistical analysis used to answer the second research question about the effectiveness of MAEA programs in terms of the relative changes in learning environment and attitudes experienced by MAEA and comparison students. The methods of statistical analysis for my third research question (concerning associations between the learning environment and student attitudes) are considered in Section 3.4.3.

3.4.1 Validation of WIHIC and TOSRA

The modified WIHIC was validated using factor analysis (principal axis factoring with varimax rotation and Kaiser normalization). Factor analyses were conducted separately for pretest data and for posttest data for the entire sample of 269 students. An item was retained only if its factor loading was at least 0.40 on its *a priori* scale and less than 0.40 with each of the other scales. Potentially the application of these criteria could lead to the deletion of some items in some scales to improve the factor structure (see Chapter 4, Section 4.2 for further details).

The factor analyses also were used to generate the percentage of variance accounted for by different WIHIC scales, as well as the total variance for all scales, separately for the pretest and the posttest. As well, the eigenvalues for the WIHIC scales were checked for the pretest and the posttest. If a scale has an eigenvalue of less than 1.0, then it would typically be omitted because the information gained from it would be insufficient to justify its retention (Leach, Barrett & Morgan, 2005, p. 82).

The internal consistency reliability (Cronbach alpha coefficient) was determined for each WIHIC scale. The alpha coefficient measures how well a set of items in a scale measures a single, unidimensional underlying theme (Cronbach, 1951). Many researchers only use a scale if the Cronbach alpha coefficient is greater than 0.70 (Cronbach & Shavelson, 2004).

Another desirable characteristic of any learning environment scale is that students in the same class should perceive their learning environment in a similar way, while mean class perceptions vary from class to class. Through using an ANOVA, the ability of each learning environment scale of the WIHIC to differentiate between perceptions of students in different classrooms was investigated. The eta^2 statistic, which represents the proportion of variance in scale scores accounted for by class membership, was calculated by taking the ratio of 'between' to 'total' sums of squares.

Similarly, the modified two-scale TOSRA also was validated using factor analysis (principal axis factoring with varimax rotation and Kaiser normalization) separately for pretest and posttest data. An item was retained only if its factor loading was at least 0.40 on its *a priori* scale and less than 0.40 on the other scale.

Again, the factor analyses for the TOSRA were used to provide the percentage of variance and eigenvalue for each scale.

As for WIHIC scales, the internal consistency reliability (Cronbach alpha coefficient) for the two TOSRA scales was calculated separately for pretest and posttest data to provide information about scale internal consistency.

3.4.2 Relative Effectiveness of MAEA: Differences between MAEA and Comparison Schools in Learning Environment Perceptions and Attitudes to Science

This section describes the data analyses used to respond to my second research question: Are there differences between science students from MAEA and comparison schools in terms of (a) their classroom learning environment perceptions and (b) attitudes to science?

To ascertain the statistical significance of differences between pretest and posttest in terms of students' perceptions of the learning environment and attitudes toward science, scores for each scale of the WIHIC and TOSRA were analyzed using MANOVA with repeated measures. Analyses for pretest–posttest changes were conducted separately for MAEA and comparison schools. If the multivariate tests using Wilks' lambda criterion revealed statistically significant pre–post changes for the set of seven learning environment and attitude scales as a whole for MAEA, then individual univariate ANOVA would be interpreted separately for each dependent variable.

Whereas the ANOVA results provided information about the statistical significance of pre–post changes, effect sizes were also calculated to provide information about the magnitude or educational importance of those changes. The reporting of effect sizes has been advocated by Cohen (1992) and Thompson (1998, 2002). Cohen's *d* effect size for each scale, which was calculated by dividing the difference between the pretest and posttest means by the pooled standard deviation, was used to express the difference in standard deviation units.

The average item mean and average item standard deviation for each learning environment and attitude scale were calculated separately for MAEA and comparison schools and separately for pretest and posttest. The average item mean (or the scale mean divided by the number of items in that scale) permits meaningful comparison of the means of different scales containing differing numbers of items. To aid interpretation, effect sizes for pre–post differences were portrayed separately for MAEA and comparison schools using a graph.

3.4.3 Associations between Learning Environment and Student Attitudes

Associations between students' perceptions of the classroom learning environment (as assessed by five scales of the WIHIC) and their attitudes towards science (as assessed by the two TOSRA scales) were the focus of my third research question. These associations were investigated separately for pretest and posttest data for my total sample of 269 grade 8 students using simple correlations, standardized regression coefficients and multiple correlations between each attitude scale and the five classroom environment scales.

The simple correlation analysis provided the bivariate relationship between each attitude scale and each environment scale. The multiple regression analysis provided information about the multivariate association between an attitude scale and the set of five environment scales. Standardized regression coefficients were used to identify which environment scales contributed uniquely and significantly to the explanation of the variance in an attitude scale when all other WIHIC scales were mutually controlled.

3.5 CHAPTER SUMMARY

This chapter was devoted to describing the research design and methods used in my study involving a comparative evaluation of MAEA's interactive science programs in terms of classroom environment and students' attitudes.

The sample consisted of grade 8 students in three schools in the Columbus City School District in Ohio. The MAEA program was implemented with 85 students in one school and there were 183 students in two comparison (non-MAEA) schools. The three schools were fairly similar to each other, and to the Columbus City Schools district overall, in terms of their very large proportions of economically disadvantaged students.

Students' perceptions of their classroom learning environment were assessed using five scales selected for their relevance from the seven-scale What Is Happening In this Class? (WIHIC). The scales used were Cooperation, Teacher Support, Involvement, Investigation and Task Orientation. The selection of these scales was based on their salience to my study, as well as the extensive validation information available for the WIHIC from dozens of studies around the world.

Scales from the Test of Science Related Attitudes (TOSRA) were selected for measuring students' attitudes to science in my study. This versatile instrument has been validated and used successfully in dozens of studies in numerous countries. From TOSRA's seven scales, I selected two scales as being of central relevance to my study – Attitude to Scientific Inquiry and Enjoyment of Science Lessons.

Chapter 3 also described the methods of data analysis used for answering each of my research questions. The modified WIHIC and TOSRA were validated using principal axis factor analysis with varimax rotation and Kaiser normalization. Items were retained only if their factor loadings were at least 0.40 on their own scale and less than 0.40 on all other scales. The internal consistency reliability for each scale was calculated using Cronbach's alpha coefficient.

MAEA and comparison groups were compared in terms of the statistical significance and magnitude of pretest–posttest changes on learning environment and attitude scales. MANOVA with repeated measure was used to ascertain the statistical significance of the pretest–posttest changes for each scale for each instructional group, whereas the magnitudes pretest–posttest differences were expressed in standard deviations using Cohen's *d* effect size.

The third research questions, involving associations between the two attitude scales and the five learning environment scales, was answered using simple correlation and multiple regression analyses. Simple correlations were used to describe the bivariate association between each attitude scale and each WIHIC scale, whereas regression coefficients were used to describe the multivariate association between each attitude scale and each environment scale when all the other environment scales were mutually controlled.

Chapter 4

RESULTS

I find that a great part of the information I have was acquired by looking for something and finding something else on the way. (Franklin P. Jones)

4.1 INTRODUCTION AND OVERVIEW

The primary purpose of my study was to evaluate the relative effectiveness of the MAEA science program among predominantly African-American students in terms of the classroom environment and students' attitudes to science. A secondary aim was to investigate associations between students' attitudes and the nature of their classroom environments.

Two instruments were modified and used in this study to assess students' classroom learning environment of their attitudes to science. From the WIHIC instrument, I choose the Cooperation, Teacher Support, Involvement, Investigation and Task Orientation scales. From the TOSRA, I used the Attitude to Scientific Inquiry and Enjoyment of Science Lessons scales. Each instrument was administered both as a pretest and a posttest. Further discussion of these instruments can be found in this thesis in Section 2.3.6 and for the WIHIC and Section 2.6 for the TOSRA.

This chapter reports analyses and results based on pretest and posttest administrations of the WIHIC and TOSRA to the 85 8th grade students at the MAEA intervention school and the 183 8th grade students at the two comparison schools. The purpose of these analyses was to answer my study's three research questions concerning:

- the validity and reliability of the WIHIC and TOSRA (Section 4.2)
- the relative effectiveness of MAEA: Differences between MAEA and comparison schools in learning environment perceptions and attitudes to science (Section 4.3)
- associations between learning environments and student attitudes (Section 4.4).

4.2 VALIDITY OF WIHIC AND TOSRA

My research involving the effectiveness of MAEA's interactive science programs necessitated choosing scales to assess students' attitudes and the classroom learning environment. From the learning environment instruments reviewed in Section 2.3 of Chapter 2, I choose the What Is Happening In this Class? (WIHIC) because of its wide prior use and its proven validity internationally. The scales of the WIHIC that I chose for my research were Cooperation, Teacher Support, Involvement, Investigation and Task Orientation. I chose these particular scales because I felt that, together, they would paint an informative picture of the students' perceptions of their science classroom learning environments. (The only WIHIC scales omitted were Student Cohesiveness and Equity.)

Additionally, to assess students' attitudes toward science, I included two scales from the Test of Science Related Attitudes (TOSRA): Attitudes to Scientific

Inquiry and Enjoyment of Science Lessons. I felt that these two scales would help in refining the picture painted by the students' views of their science classrooms by addressing their attitudes. Although there are other scales that also would have been valuable to include in the research, I did not want the resultant questionnaire to seem too long to the students, to make them reluctant to complete it, or cause fatigue that could affect their responses.

One of my research questions involved validating the questionnaires that I used for assessing the classroom environment and attitudes. Questionnaires were given to the entire 8th grade student populations in the three schools involved in the study. As discussed in Chapter 3, the comparison schools of Johnson Park and Medina provided 139 and 44 grade 8 students, respectively, making a total of 183 students. At the MAEA intervention school of Eastmoor, there were 85 grade 8 students who participated in the validation of the questionnaire. Therefore my total sample consisted of 268 students.

4.2.1 Validation of WIHIC

As described in Section 3.4.1, the five-scale version of the WIHIC was validated using factor analysis (principal axis factoring with varimax rotation and Kaiser normalization). Factor analyses were conducted separately for pretest data and for posttest data for the entire sample of 269 students. An item was retained only if its factor loading was at least 0.40 on its *a priori* scale and less than 0.40 with each of the other scales. Table 4.1 shows the factor loading for each of the 40 WIHIC items used in my study. The application of these criteria led to the deletion of some items in some scales to improve the factor structure. Four items were removed from the Involvement scale and one item was removed from the Cooperation scale. After removal of these five items, Table 4.1 shows that all of the remaining items had a loading of at least 0.40 on their own scale and less than 0.40 on all other WIHIC scales.

The bottom of Table 4.1 shows that the percentage of variance accounted for ranged from 3.77% to 33.21% for different scales, with a total variance of 60.64% for the pretest, and from 3.32% to 33.36% for different scales, with a total variance of 59.68% for the posttest. The cumulative variance total is consistent with values reported in past learning environment studies that involved using the WIHIC (Chionh & Fraser, 2009; Dorman, 2003).

The eigenvalues for the WIHIC scales ranged from 1.35 to 11.95 for the pretest and from 1.16 to 11.68 for the posttest. If a scale has an eigenvalue of less than 1.0, then it would typically be omitted because the information gained from it would be considered insufficient to warrant its retention (Leach et al., 2005, p. 82). Overall, the factor analysis results shown in Table 4.1 support the *a priori* structure of the WIHIC questionnaire.

Table 4.2 shows the internal consistency reliability (Cronbach alpha coefficient) for each WIHIC scale. The alpha coefficient (see Section 3.4.1) measures how well a set of items in a scale measures a single, unidimensional underlying theme (Cronbach, 1951). The WIHIC scales showed high internal consistency reliability with values ranging from 0.78 to 0.92 for different scales for the prestest and from 0.80 to 0.91 for the posttest. Many researchers only use a scale if the Cronbach alpha coefficient is greater than 0.70 (Cronbach & Shavelson, 2004).

Cronbach himself, prior to his death in 2001, noted that the alpha coefficient only covers a small part of a full range of measurement uses that require internal reliability, and therefore that the alpha coefficient should be used as one of numerous reliability indicators that should be considered (Cronbach & Shavelson, 2004).

Table 4.1 Factor Analysis Results for WIHIC for Pretest and Posttest

Item No	Cooperation		Teacher Support		Involvement		Investigation		Task Orientation	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	0.55	0.52								
3	0.57	0.43								
4	0.55	0.67								
5	0.42	0.51								
6	0.61	0.71								
7	0.65	0.72								
8	0.54	0.54								
9			0.66	0.66						
10			0.77	0.78						
11			0.81	0.75						
12			0.75	0.71						
13			0.79	0.79						
14			0.75	0.78						
15			0.61	0.69						
16			0.68	0.71						
17					0.62	0.61				
18					0.70	0.63				
20					0.40	0.53				
22					0.52	0.33				
25							0.62	0.56		
26							0.61	0.56		
27							0.65	0.59		
28							0.58	0.54		
29							0.68	0.67		
30							0.76	0.66		
31							0.57	0.66		
32							0.51	0.67		
33									0.62	0.56
34									0.75	0.67
35									0.77	0.70
36									0.77	0.69
37									0.74	0.74
38									0.65	0.63
39									0.76	0.64
40									0.71	0.65
% Variance	33.21	33.36	10.24	9.87	7.83	7.39	5.59	5.74	3.77	3.32
Eigenvalue	11.95	11.68	3.68	3.45	2.82	2.58	2.01	2.01	1.35	1.16

N = 269
Item 2,19,21,23 and 24 were omitted.
Factor loadings less than 0.40 have been omitted from the table.
Method: Principal axis factoring with varimax rotation and Kaiser normalization.

Another desirable characteristic of any learning environment scale is that students in the same class should perceive their learning environment in a similar way, while mean class perceptions vary from class to class. By using an ANOVA, the ability of each learning environment scale of the WIHIC to differentiate between perceptions of students in different classrooms was investigated. The ANOVA results in the last column of Table 4.2 reveal that a statistically significant difference ($p<0.01$) between the perceptions of students in different classes occurred for each learning environment scale for both pretest and posttest data. (This characteristic is not relevant for the two attitude scales.)

The eta^2 statistic, which represents the proportion of variance in scale scores accounted for by class membership, ranged from 0.15 to 0.24 for the pretest and from 0.12 to 0.20 for the posttest for the different learning environment scales.

4.2.2 Validation of TOSRA

The modified two-scale TOSRA also was validated using factor analysis (principal axis factoring with varimax rotation and Kaiser normalization). An item was retained only if its factor loading was at least 0.40 on its *a priori* scale and less than 0.40 on the other scale. No TOSRA items were omitted during this factor analysis because all items satisfied the two criteria. The factor loadings shown in Table 4.3 support the two-scale structure of the TOSRA.

Table 4.2 Mean, Standard Deviation, Internal Consistency (Cronbach Alpha Reliability) and Ability to Differentiate between Schools (ANOVA Results) for Learning Environment and Attitude Scales

Scale	No of Items	Mean		SD		Alpha Reliability		Eta^2	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Learning Environment									
Cooperation	8	3.73	3.78	0.68	0.67	0.78	0.82	0.18**	0.12**
Teacher Support	8	3.39	3.47	0.99	0.90	0.92	0.91	0.24**	0.20**
Involvement	4	3.33	3.50	0.93	0.87	0.82	0.80	0.17**	0.16**
Investigation	8	3.34	3.56	0.85	0.77	0.91	0.89	0.17**	0.17**
Task orientation	8	4.18	4.15	0.76	0.66	0.91	0.89	0.15**	0.20**
Attitudes									
Attitude to Scientific Inquiry	8	3.47	3.68	1.09	0.98	0.92	0.91		
Enjoyment of Science Lessons	8	3.04	3.26	1.16	1.08	0.94	0.94		

N=269

***p*<0.01

Eta^2 is the ratio of 'between' to 'total' sums of squares and represents the proportion of variance accounted for by class membership.

The bottom of Table 4.3 shows that the percentage of variance accounted for was 25.35% for Enjoyment of Science Lessons and 44.23% for Attitude to Scientific Inquiry, with the total variance being 69.58% for the pretest, and 23.62% for Enjoyment of Science Lessons and 43.19% for Attitude to Scientific Inquiry, with a total of 66.81% for the posttest. The eigenvalues for the two TOSRA scales were 4.05 and 7.07 for the pretest and were 3.78 to 6.91 for the posttest. As with the WIHIC items, if a TOSRA scale showed an eigenvalue less than 1.0, then scale would typically be omitted because the information gained from the item would be deemed insufficient to justify retention.

Table 4.2 shows that the internal consistency reliability (Cronbach alpha coefficient) for the two TOSRA scales was high, with values of 0.92 (pretest) and 0.91 (posttest) for Attitude to Scientific Inquiry and of 0.94 (pretest) to 0.94 (posttest) for

Enjoyment of Science Lessons. (The ability to differentiate between classrooms is not relevant for attitude scales.)

Table 4.3 Factor Analysis Results for the Attitude Scales for Pretest and Posttest

Item No.	Attitude To Scientific Inquiry		Enjoyment of Science Lessons	
	Pre	Post	Pre	Post
41	0.73	0.73		
42	0.74	0.71		
43	0.82	0.75		
44	0.76	0.72		
45	0.82	0.80		
46	0.78	0.78		
47	0.70	0.69		
48	0.72	0.77		
49			0.75	0.80
50			0.83	0.68
51			0.85	0.84
52			0.87	0.85
53			0.88	0.88
54			0.81	0.72
55			0.79	0.79
56			0.84	0.88
% Variance	44.23	43.19	25.35	23.62
Eigenvalue	7.07	6.91	4.05	3.78

N=269
Factor loadings less than 0.40 have been omitted from the table.
Method: Principal axis factoring with varimax rotation and Kaiser normalization.

4.2.3 Summary of Validity Results for WIHIC and TOSRA

Although both the WIHIC and TOSRA have been validated and used in many past studies in numerous countries around the world, my study provided an opportunity to crossvalidate these instruments with a different population, namely, disadvantaged African-American eighth graders in Ohio. Overall, my results regarding the validity and reliability of the WIHIC crossvalidate considerable past research, in terms of factor structure and scale reliability, such as the following selection of previous studies:

- in California with samples of 665 middle-school science students (den Brok et al., 2006), 661 middle-school mathematics students (Ogbuehi & Fraser, 2007) and 745 high-school mathematics students (Taylor & Fraser, 2012, 2013)
- in Florida with samples of 573 grade 3–5 science students (Pickett & Fraser, 2009), 520 grade 4 and 5 science students (Robinson & Fraser, 2013) and 924 grade 8 and 10 science students (Helding & Fraser, 2013)
- in Singapore with samples of 2310 grade 10 geography and mathematics students (Chionh & Fraser, 2009), 250 working adults attending computer education courses (Khoo & Fraser, 2008), and 1460 secondary 3 Chinese-language students (Chua, Wong & Chen, 2011).
- in the United Arab Emirates with samples of 763 college students (MacLeod & Fraser, 2010) and 352 college students (Afari et al., 2013)
- with junior high science students in Taiwan (1879 students) and Australia (1081 students) (Aldridge et al., 1999)
- in Australia, the UK and Canada with 3980 high school students (Dorman, 2003)
- with secondary science students in Indonesia (594 students) and Australia (567 students) (Fraser et al., 2010).

For example, the WIHIC scale reliabilities ranging from 0.82 to 0.91 for the posttest in my study (Table 4.2) compare favorably with those reported by other researchers, such as Helding and Fraser (2013) in the USA (0.82–0.92), Dorman (2003) in Australia, UK and Canada (0.76–0.85), and Aldridge, Fraser and Huang (1999) in Taiwan (0.85–0.90).

Regarding the TOSRA, my results replicate many past studies that have supported its factorial validity and internal consistency reliability with science students around the world (Fraser, 1981a; Fraser, Aldridge & Adolphe, 2010; Joyce & Farenga, 1999; Kalili, 1987; Quek, Wong & Fraser, 2005b; Wong & Fraser, 1996). In addition, the TOSRA has been found to be valid when modified to assess attitudes in other subject areas, including geography (Walker, 2006), Spanish (Adamski, Fraser & Peiro, 2013), mathematics (Ogbuehi & Fraser, 2007) and English (Liu & Fraser, 2013). For example, the reliability values of 0.91 and 0.94 for the posttest for the two TOSRA scales used in my study compare favorably with the coefficients also of 0.91 and 0.94 reported by Peer and Fraser (in press) for a sample of 1081 primary-school science students in Singapore.

4.3 RELATIVE EFFECTIVENESS OF MAEA: DIFFERENCES BETWEEN MAEA AND COMPARISON SCHOOLS IN LEARNING ENVIRONMENT PERCEPTIONS AND ATTITUDES TO SCIENCE

This section reports results that answer my second research question: Are there differences between science students from MAEA and comparison schools in terms of (a) their classroom learning environment perceptions and (b) attitudes to science?

As described in Section 3.4.2, I ascertained the statistical significance of differences between pretest and posttest in terms of students' perceptions of the learning environment and attitudes toward science, I analyzed scores for each scale of the WIHIC and TOSRA using MANOVA with repeated measures. Analyses for pretest–posttest changes were conducted separately for MAEA and comparison schools changes. Because the multivariate tests using Wilks' lambda criterion revealed statistically significant pre–post changes for the set of seven learning environment and attitude scales as a whole for MAEA, the individual univariate ANOVA was interpreted separately for each dependent variable. (MANOVA revealed nonsignificant pre–post changes overall for the comparison group.)

ANOVA results for the statistical significance of pre–post changes were complemented by effect sizes to provide information about the magnitude or educational importance of those changes. The reporting of effect sizes has been advocated by Cohen (1992) and Thompson (1998, 2002). The effect size for each scale (Cohen's *d*), which was calculated by dividing the difference between the pretest and posttest means by the pooled standard deviation, expresses the difference in standard deviation units.

Table 4.4 reports the average item mean and average item standard deviation for each learning environment and attitude scale separately for MAEA and comparison schools and separately for pretest and posttest. The average item mean (or the scale mean divided by the number of items in that scale) permits meaningful comparison of the means of different scales containing differing numbers of items.

Table 4.4 also reports, separately for MAEA and comparison schools, the statistical significance of pre–post changes for each scale based on ANOVA, as well as the magnitude of the pre–post difference for each scale expressed as an effect size in standard deviation units. Finally, to clarify further the patterns of similarities and differences between MAEA and comparison schools, the effect size for pre–post differences on each scale is graphed separately for MAEA and comparison schools in Figure 4.1.

For the comparison schools, Table 4.4 and Figure 4.1 show that pre–post changes in learning environment and attitude scales:

- were statistically nonsignificant for each of the seven environment and attitude scales
- were small in magnitude for all seven scales (ranging in magnitude from only 0.05 to 0.20 standard deviations)
- represent a small decline in scores between pretest and posttest for several scales (Cooperation, Teacher Support, Task Orientation).

Table 4.4 Average Item Mean, Average Standard Deviation and Difference between Pretest and Posttest (Effect Size and ANOVA Results) in Learning Environment and Attitude Scores Separately for MAEA and Comparison Schools

Scale	Schools	Average item Mean		Average Item SD		Difference	
		Pre	Post	Pre	Post	Effect Size	*F*
Learning Environment							
Cooperation	MAEA	3.43	3.67	0.77	0.71	0.32	4.42*
	Comparison	3.85	3.82	0.59	0.65	-0.05	0.21
Teacher Support	MAEA	2.67	3.16	1.12	1.05	0.45	8.55**
	Comparison	3.72	3.57	0.71	0.82	-0.20	3.53
Involvement	MAEA	3.00	3.15	0.99	0.89	0.16	1.08
	Comparison	3.49	3.63	0.86	0.83	0.17	2.52
Investigation	MAEA	2.99	3.22	0.89	0.81	0.27	3.13
	Comparison	3.51	3.65	0.79	0.72	0.19	3.13
Task Orientation	MAEA	3.90	4.03	0.89	0.76	0.16	1.04
	Comparison	4.30	4.18	0.67	0.61	-0.19	3.22
Attitudes							
Attitude to Scientific Inquiry	MAEA	3.36	3.70	1.05	0.92	0.34	5.06*
	Comparison	3.51	3.67	1.11	1.00	0.15	2.07
Enjoyment of Science Lessons	MAEA	2.56	3.11	1.22	1.19	0.46	8.96**
	Comparison	3.23	3.31	1.00	1.03	0.08	0.60

*$p<0.05$
**$p<0.01$
N=85 (MAEA) and 184 (comparison)

On the other hand, for the MAEA school, Table 4.4 and Figure 4.1 show that pre–post changes in learning environment and attitude scales:

- were statistically significant ($p<0.05$) for the two learning environment scales of Cooperation and Teacher Support and for both attitude scales of Attitude and Scientific Inquiry and Enjoyment of Science Lessons.
- were of moderate magnitude for the four scales for which pre–post differences were significant, namely, Cooperation (0.32 standard deviations), Teacher Support (0.45 standard deviations), Attitude to Scientific Inquiry (0.34 standard deviations) and Enjoyment of Science Lessons (0.46 standard deviations).
- represent an increase in scores between pretest and posttest for every scale.

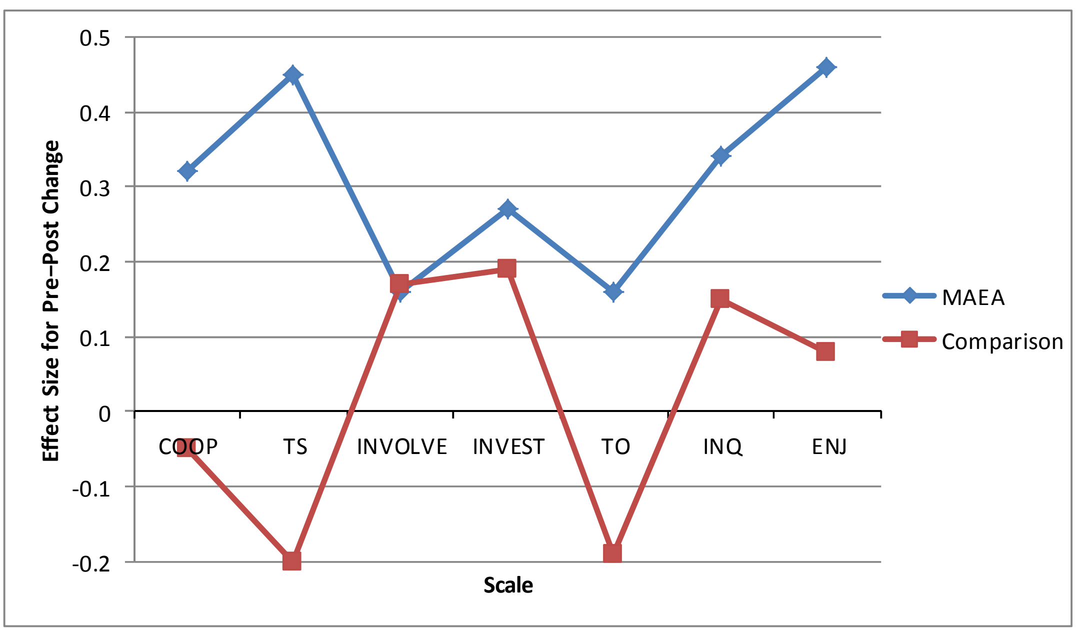

Figure 4.1 Effect Size for Pretest–Posttest Changes in Learning Environment and Attitude Scales

Overall the results in Table 4.4 provide some tentative support for the effectiveness of MAEA's interactive programs with African-American middle-school students in terms of larger pre–post changes in classroom learning environment and students' attitudes to science relative to comparison schools.

4.4 ASSOCIATIONS BETWEEN LEARNING ENVIRONMENT AND STUDENT ATTITUDES

Associations between students' perceptions of the classroom learning environment (as assessed by five scales of the WIHIC and their attitudes towards science (as assessed by the two TOSRA scales) were the focus of my third research question and are reported in Table 4.5. These associations were investigated separately for pretest and posttest data for my total sample of 269 grade 8 students. The statistics reported in Table 4.5 are simple correlations, standardized regression coefficients and the multiple correlation between each attitude scale and the five classroom environment scales.

As discussed in Section 3.4.3, the simple correlation analysis (*r*) is appropriate for examining the bivariate relationship between an attitude scale and a learning environment scale. The multiple regression analysis provides information about the multivariate association between an attitude scale and the set of five environment scales. Using standardized regression coefficients (β), we can identify which environment scales contribute uniquely and significantly to the explanation of the variance in an attitude scale when all other WIHIC scales are mutually controlled.

Table 4.5 shows that all of the environment scales were statistically significantly correlated ($p<0.01$) with students' Enjoyment of Science Lessons for both the pretest and posttest data. For Attitude to Scientific Inquiry, the correlation was statistically significant ($p<0.05$) for both pretest and posttest data for Cooperation, Investigation and Task Orientation and also for Involvement for the pretest data.

Table 4.5 Simple Correlation and Multiple Regression Analyses for Associations Between the Learning Environment and Attitude Scales for Pretest and Posttest

Scale	Administration	Attitude–Environment Association			
		Attitude to Scientific Inquiry		Enjoyment of Science Lessons	
		r	β	*r*	β
Cooperation	Pretest	0.14*	0.03	0.21**	0.00
	Posttest	0.15*	0.04	0.24**	0.00
Teacher Support	Pretest	0.08	0.09	0.45**	0.36**
	Posttest	0.07	0.08	0.47**	0.34**
Involvement	Pretest	0.14*	0.03	0.19**	0.12
	Posttest	0.08	0.15*	0.29**	0.02
Investigation	Pretest	0.17*	0.06	0.33**	0.08
	Posttest	0.20**	0.18*	0.38**	0.11
Task Orientation	Pretest	0.32**	0.31**	0.41**	0.27**
	Posttest	0.29**	0.28**	0.34**	0.14
Multiple Correlation (*R*)	Pretest	0.33**		0.53**	
	Posttest	0.32**		0.51**	

*$p<0.05$, **$p<0.01$
$N=269$

The multiple correlations (R) reported at the bottom of Table 4.5 for the set of five WIHIC scales was statistically significant ($p<0.01$) for each of the two attitude scales for both pretest and posttest data.

To identify which classroom environment scales contributed most to the variance in a specific attitude scale, the standardized regression weights (β) were examined. Table 4.5 shows that:

- Teacher Support was a statistically significant independent predictor of Enjoyment of Science Lessons for both pretest and posttest data.
- Involvement was a statistically significant predictor of Attitude to Scientific Inquiry for the posttest data.
- Investigation was a statistically significant predictor of Attitude to Scientific Inquiry for the posttest data.
- Task Orientation was a statistically significant independent predictor of Attitude to Scientific Inquiry for both pretest and posttest data and of Enjoyment of Science Lessons for pretest data.

It is noteworthy that all statistically significant simple correlations and regression coefficients in Table 4.5 are positive, suggesting that a positive relationship existed between a more favorable classroom learning environment and students' attitudes. This replicates considerable prior research in many countries (Fraser, 2012; Fraser & Fisher, 1982; Fraser & Kahle, 2007; McRobbie & Fraser, 1993; Wong, Young & Fraser, 1997) which revealed positive and statistically-significant relationships between students' attitudes to science and their perceptions of the classroom learning environment.

4.5 CHAPTER SUMMARY

This chapter reported the data analyses and results for each of my study's three research questions involving: the validation of learning environment and attitude questionnaires; the relative effectiveness of MAEA; and associations between classroom environment and student attitudes. The sample consisted of 85 grade 8 students at the MAEA intervention school and 183 grade 8 students at the comparison schools. Scales were selected from the What Is Happening In this Class? (WIHIC) to assess students' perceptions of five dimensions of their learning environments and from the Test of Science Related Attitudes (TOSRA) to assess two dimensions of students' attitudes to science.

My first research question involved whether the WIHIC and TOSRA were valid when used with my sample of disadvantaged African-American students. I conducted principal axis factor analysis with varimax rotation and Kaiser normalization for the questionnaire to check its structure. The criteria used for the retention of any item were that its factor loading had to be at least 0.40 on its own scale and less than 0.40 on the other scales in the questionnaire. A factor analysis was conducted separately for the pretest and posttest data.

For the 5-scale 40-item WIHIC, five items did not meet the criteria for retention and were removed prior to conducting further analyses. For the refined 35-item version of the WIHIC, the a priori 5-sclae structure was replicated for both pretest and posttest. The total amount of variance accounted for was 60.64% for the pretest and 59.68% for the posttest. Scale eigenvalues ranged from 1.35 to 11.95 for the pretest and from 1.16 to 11.68 for the posttest.

For the 2-scale 16-item TOSRA, all items satisfied the criteria for retention. The percentage of variance accounted for by the two scales was 69.58% for the pretest and 66.81% for the posttest. The eigenvalues were 4.05 and 7.07 for the pretest and 3.78 and 6.91 for the posttest.

The internal consistency reliability using Cronbach's alpha coefficient was found to be high for all WIHIC and TOSRA scales for both pretest and posttest data. Alpha coefficients for WIHIC scales ranged from 0.78 to 0.92 for pretest data and from 0.82 to 0.91 for posttest data and, for TOSRA scales, reliabilities were 0.92 to 0.94 for pretest data and 0.91 and 0.94 for posttest data.

My results for the validity and reliability of the WIHIC and TOSRA specifically for a sample of disadvantaged African-American students replicate dozens of past studies in numerous countries reviewed in Chapter 2 in Section 2.3.6 for the WIHIC and Section 2.6 for the TOSRA.

My second research question involved evaluating the effectiveness of MAEA's interactive science programs by comparing MAEA and comparison schools in terms of pretest–posttest changes in scores on learning environment and attitudes scales. This involved conducting MANOVAs with repeated measures to ascertain statistical significance, as well as calculating effective sizes (Cohen's *d*) to portray the magnitude of differences in standard deviation units.

Whereas pretest–posttest changes were statistically nonsignificant for every scale for the comparison group, they were significant and of moderate magnitude (0.32 to 0.40 standard deviations) for the MAEA group for the four scales of Cooperation, Teacher Support, Attitude to Science Inquiry and Enjoyment of Science Lessons. Overall, this pattern of results for statistical significance and effect sizes provides tentative support for the effectiveness of MAEA with disadvantaged African-American middle-school students.

My third research question focused on associations between students' attitudes to science and their perceptions of the learning environment. Simple correlations were used to describe bivariate associations between attitudes and each learning environment scale, whereas multiple regression analysis was used to investigate the multivariate association between each attitude scale and a particular learning environment scale when the other four WIHIC scales were mutually controlled. Much prior research was replicated in that it was found that more classroom emphasis on each of the WIHIC's learning environment scales was associated with more positive student attitudes.

Chapter 5

CONCLUSION

5.1 CHAPTER INTRODUCTION

This thesis is devoted to reporting my comparative evaluation of the use of MAEA's interactive science programs among disadvantaged African-American middle-school science students. This concluding chapter begins by providing a summary of the thesis in Section 5.2. Then the study's limitations are discussed in Section 5.3, which leads naturally to suggestions for future research in Section 5.4. Finally, some implications and contributions of the study are drawn out in Section 5.5.

5.2 SUMMARY OF PREVIOUS CHAPTERS

5.2.1 Summary of the Introductory Chapter

Chapter 1 began with my personal history, how I founded MAEA and developed interactive science programs for disadvantaged African-American students, and how this motivated me to embark on the present doctoral study (Section 1.2). The aims of my research were delineated in Section 1.3. In Section 1.4, I briefly introduced the significance of my study (Section 1.4.1) and contextualized my study in terms of the Columbus City School District (Section 1.4.2), inquiry-based science teaching (Section 1.4.3), and the field of classroom learning environments (Section 1.4.4) in which my study was located.

5.2.2 Summary of Literature Review Chapter

Because my evaluation involved student perceptions of their learning environments as criteria of effectiveness, Chapter 2's central aim was to provide a comprehensive review of literature in this field. Also, because students' attitudes to science were included in my study, a review of literature about attitudes was included in this chapter. Because past research seldom specifically involved samples of African-American students, the thrust of my literature review was to provide comprehensive coverage of all relevant past research conducted with samples from around the world.

A brief historical overview on the field of learning environments started with the seminal foundations of Walberg and Moos in the late 1960s and then traced developments to the present day. Because questionnaires have played such an important role in research on learning environments, a review was provided of historically-significant and contemporary questionnaires, such as the What Is Happening In this Class? (WIHIC), Questionnaire on Teacher Interaction (QTI), Science Laboratory Environment Inventory (SLEI), and Constructivist Learning Environment Survey (CLES).

Because the WIHIC questionnaire was used to assess classroom environment in my study, reviewing past studies that employed the WIHIC around the world in many research applications was a particular focus of this chapter. In particular,

Table 2.2 summarized the details of 28 studies involving the use of the WIHIC in numerous languages and countries.

Prior studies of learning environments were reviewed using two methods of organization. In Section 2.4, past studies were grouped into five themes: evaluation of educational innovations; associations between student outcomes and classroom environment; improving classroom environments; investigation of multiple environments; cross-national studies; and typologies of classroom environments. Second, in Section 2.5, I reviewed past studies according to the countries in which they were conducted: Asia; North America; and African and Arab countries.

Finally, Section 2.6 of Chapter 2 focused on literature about the conceptualization and assessment of attitudes. Particular attention was given to the Test of Science Related Attitudes (TOSRA) because I drew scales from it for inclusion in my study.

5.2.3 Summary of Chapter about Research Methods

Chapter 3 focused on my research design and research methods for a comparative evaluation of MAEA's interactive science programs in terms of classroom environment and students' attitudes. The sample consisted of grade 8 students in three schools in the Columbus City School District in Ohio. The MAEA program was implemented with 85 students in one school and there were 183 students in two comparison schools. The three schools were fairly comparable to each other, as well as being fairly representative of the Columbus City School

District overall in terms of its very large proportions of disadvantaged African-American students.

Students' perceptions of their classroom learning environment were assessed using five relevant scales from the seven-scale What Is Happening In this Class? (WIHIC): Cooperation, Teacher Support, Involvement, Investigation and Task Orientation. The selection of these scales was based on their relevance to my study, as well as their extensive validation in dozens of studies around the world reviewed in Section 2.3.6 of Chapter 2.

Scales from the Test of Science Related Attitudes (TOSRA) were selected for measuring students' attitudes to science in my study. TOSRA has been validated and used successfully in dozens of studies (see review in Section 2.6 of Chapter 2). From TOSRA's seven scales, I selected Attitude to Scientific Inquiry and Enjoyment of Science Lessons as being of central relevance to my study.

Chapter 3 also included the methods of data analysis for answering my research questions. The modified WIHIC and TOSRA were validated using principal axis factor analysis with varimax rotation and Kaiser normalization, with items being retained only if their factor loadings were at least 0.40 on their own scale and less than 0.40 on all other scales. Also the internal consistency reliability for each scale was calculated using Cronbach's alpha coefficient.

MAEA and control students were compared in terms of both the statistical significance and magnitude of pretest–posttest changes in scores on learning environment and attitude scales. MANOVA with repeated measure was used to investigate the statistical significance of the pretest–posttest changes for each scale for each instructional group. Also the magnitude of pretest–posttest differences for each scale was expressed in standard deviations as an effect size (Cohen's *d*).

The third research question, involving associations between the two attitude scales and the five learning environment scales, was answered using simple correlation and multiple regression analyses. Simple correlations were used to investigate the bivariate association between each attitude scale and each WIHIC scale, whereas regression coefficients were used to examine the multivariate association between each attitude scale and each environment scale when all the other environment scales were mutually controlled.

5.2.4 Summary of Results Chapter

Chapter 4 was devoted to the data analyses and results for my study's three research questions: validation of five learning environment scales from the WIHIC and two attitude scales from TOSRA; a comparative evaluation of MAEA; and associations between classroom environment and student attitudes.

The first research question focused on whether the WIHIC and TOSRA were valid when used with my sample of 268 disadvantaged African-American students. Principal axis factor analysis with varimax rotation and Kaiser normalization was used to check the structure of each questionnaire. The criteria used for the retention of any item were that its factor loading had to be at least 0.40 on its own scale and less than 0.40 on the other scales in the questionnaire. A factor analysis was constructed separately for the pretest and posttest data.

For the 5-scale 40-item WIHIC, five items did not meet the criteria for retention and were removed prior to conducting further analyses. For the remaining 35 items, the a priori 5-scale structure was replicated for both pretest and posttest. The total amount of variance accounted for was 60.64% for the pretest and 59.68% for the posttest. Scale eigenvalues ranged from 1.35 to 11.95 for the pretest and from 1.16 to 11.68 for the posttest. For the 2-scale 16-item TOSRA, all items satisfied the criteria for retention. The percentage of variance accounted for by the two scales was 69.58% for the pretest and 66.81% for the posttest. The eigenvalues were 4.05 and 7.07 for the pretest and 3.78 and 6.91 for the posttest.

The internal consistency reliability (Cronbach's alpha coefficient) was high for all WIHIC and TOSRA scales for both pretest and posttest data. Alpha coefficients for WIHIC scales ranged from 0.78 to 0.92 for pretest data and from 0.82 to 0.91 for posttest data, and for TOSRA scales were 0.92 and 0.94 for pretest data and 0.91 and 0.94 for posttest data. Clearly, my validity and reliability results for the WIHIC and TOSRA, when used with a sample of disadvantaged African-American students, replicated much research in numerous countries reviewed in Chapter 2 in Section 2.3.6 for the WIHIC and Section 2.6 for the TOSRA.

My second research question focused on evaluating MAEA's relative effectiveness and involved comparing MAEA and comparison schools in terms of pretest–posttest changes in scores on learning environment and attitudes scales. MANOVAs with repeated measures were used to investigate statistical significance, whereas effective sizes (Cohen's *d*) described the magnitude of differences in standard deviation units.

Pretest–posttest changes were statistically nonsignificant for every scale for the comparison group. But they were significant and of moderate magnitude (0.32 to 0.40 standard deviations) for the MAEA group for the four scales of Cooperation, Teacher Support, Attitude to Science Inquiry and Enjoyment of Science Lessons. This pattern of results tentatively supported the effectiveness of MAEA programs when used with disadvantaged African-American middle-school students.

My last research question involved associations between students' attitudes to science and their perceptions of the learning environment. Simple correlations were used to examine bivariate associations between and attitudes and each learning environment scale, whereas multiple regression analysis was used to ascertain the multivariate association between each attitude scale and learning environment scale when the other four WIHIC scales were mutually controlled. Prior research was replicated in that more classroom emphasis on each of the WIHIC's learning environment scales was associated with more positive student attitudes.

5.3 LIMITATIONS OF THE STUDY

It is acknowledged that, despite careful planning and taking every precaution to ensure that my data were free from errors or bias, my study still had some limitations. As with every study, inevitably, sampling limitations arose. My limited sample size of 269 students would have led to somewhat limited statistical power being associated with statistical significance tests and could have led to less accurate results.

While practical constraints meant that my study was limited to three schools in one school district, it is recognized that the generalizability of my findings was somewhat limited. With more resources, a larger and more diverse sample might have been drawn from more schools in this district, as well as from other districts catering for disadvantaged African-American students.

Although the questionnaire used in my study were convenient and economical, it is possible that some students misunderstood some items or distorted their responses to what they believed was expected of them. It was not feasible to include all salient constructs in the questionnaire.

For the experimental group experiencing MAEA's interactive science programs, I was the teacher. Therefore, a potential limitation of my study is that its results might not be generalizable to other instructors.

In any study, only a limited number of variables can be included. My study's criteria of curricular effectiveness were classroom learning environment and students' attitudes were relevant and important, but inevitably other criteria were omitted for reasons of economy. In particular, the inclusion of important achievement criteria would have been worthwhile.

Not all students in the classes in my study responded to the questionnaires for a variety of reasons, including not having parental permission, being absent from class on the day when the survey was administered, or because the survey appeared to lack relevance to them. Because my study involved a pretest and a posttest, only students who were present on both testing occasions could be included in my data analysis. Also, because of the transient nature of the student population in the Columbus City School District, quite a few students who responded to my pretest questionnaire had left their school by the time of posttesting.

Although the types of statistical analysis chosen for my research were quite adequate for my somewhat pioneering and exploratory study, perhaps more sophisticated analyses might have been chosen. For example, the somewhat limited sample size made it difficult to conduct analyses using the class mean as the unit of analysis or to use multilevel analysis. Because the correlation and multiple regression analyses used to investigate relationships between the student outcomes and learning environment can only detect linear relationships, any existing non-linear relationships would be missed. Confirmatory factor analysis might have been used in addition to explanatory factor analysis.

Another limitation is that using qualitative methods was beyond the scope and resources of my study. The merits of combining qualitative and quantitative methods in learning environment research have been discussed by Tobin and Fraser (1998). The absence of qualitative information potentially could have led to some loss of insights which could have illuminated and explained the findings from my use of questionnaires.

5.4 SUGGESTIONS FOR FUTURE RESEARCH

The limitations identified in Section 5.3 lead to numerous suggestions for future research. The fact that my sample was somewhat limited in size and scope suggests the desirability in future research of having larger samples in order to achieve greater statistical power and representativeness in order to improve the generalizability of results. For example, future samples could extend to other grade levels, other instructors, other schools and other school districts.

The absence of a measure of student achievement in my study leads to a recommendation for its inclusion in future studies.

Because my study was limited to the use of quantitative methods based on questionnaires, the inclusion of qualitative methods is recommended in future research in an attempt to acquire new insights and explain questionnaire findings. Furthermore, mixed-methods studies that combine qualitative and quantitative methods are likely to be more productive than the use of either method alone.

The What Is Happening In this Class? (WIHIC), which was cross-validated in my study with disadvantaged African-Americans could be used in future research with this population in some of the lines of research identified by Fraser (2012) and reviewed in Section 2.3. These include investigation of differences between students' and teachers' perceptions, whether students achieve better in their preferred environment, links between environments (e.g. home, peer-group and university environments), and instructors' attempts to improve their classroom environments.

In future research with a larger sample, methods of statistical analysis could be more sophisticated than those used in my study. For example, confirmatory factor analysis could be used as well as exploratory factor analysis. The class mean could be used and the unit of analysis in addition to the student. Multilevel analysis could be used in addition to multiple regression analysis. Non-linear relationships could be investigated as well as linear relationships.

5.5 IMPLICATIONS AND CONTRIBUTIONS

The main substantive contribution of this research is that it is one of the first learning environment studies to involve a sample of disadvantaged African-American students.

A methodological contribution is that learning environment and attitude questionnaires were cross-validated for future use by researchers and practitioners working with disadvantaged African-Americans. As a result of my study, researchers and teachers now have validated and economical questionnaires for assessing classroom environments and students' attitudes to science among this population.

A practical implication is that, because MAEA's interactive science programs were tentatively found to be effective in terms of learning environment and attitude criteria, they are recommended for further use with disadvantaged African-American students.

My tentative results concerning associations between emphases in the classroom environment and improved student attitudes have potential practical implications for the improvement of science instruction for this population. For example, Teacher Support was the strongest predictor of Enjoyment of Science Lessons and Task Orientation was the strongest predictor of Attitude to Scientific Inquiry. These findings tentatively suggest directions for changing classroom environments, possibly using the approach followed in past studies and reviewed in

Section 2.4.3 (e.g. Aldridge et al., 2012), in an attempt to improve different types of student attitudes to science.

5.6 FINAL REMARKS

The critical importance of the teacher and the classroom environment has been described by Ginott:

> I've come to a frightening conclusion that I am the decisive element in the classroom. It's my personal approach that creates the climate. It's my daily mood that makes the weather. As a teacher, I have a tremendous power to make a child's life miserable or joyous. I can be a tool of torture or an instrument of inspiration. I can humiliate or humor, hurt or heal. In all situations, it is my response that decides whether a crises will be escalated or de-escalated and a child humanized or dehumanized. (Ginott, 1971, p. 13)

My evaluation of MAEA interactive science programs reported in this thesis tentatively supports Ginott's contention because, with an appropriate teacher and a positive classroom environment, disadvantaged African-American middle-school students developed positive attitudes to science.

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Appendix A

LEARNING ENVIRONMENT AND ATTITUDE QUESTIONNAIRE

Items 1–40 in this questionnaire are from the What Is Happening In this Class? (WIHIC) and Items 41–56 are from the Test of Science Related Attitudes (TOSRA). The WIHIC was developed by Fraser, Fisher and McRobbie (1996) and is described in this thesis in Sections 2.3.6 and 3.3.1. The TOSRA was developed by Fraser (1981) and is described in Sections 2.6 and 3.3.2. These questionnaire items were used in my study and are included in my thesis with the authors' permission.

How Do You Feel About Your Science Class?

Directions for Students

This questionnaire contains statements about your science class. You will be asked whether you disagree or agree with each statement.

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

For each statement, draw a circle around:

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

Be sure to give an answer for all questions. If you change your mind about an answer, just cross it out and circle another. Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about each statement.

Practice Example: Suppose you were given the statement "I go to a good school." If you selected **"Strongly Agree"** then you would circle the number SA on your questionnaire which would mean that you really like your school. If you selected **"Agree"** (A), then that would mean that you like your school most times. If you selected **"Not Sure"** (N) then that would mean that what you like and dislike about your school are about the same. If you selected **"Disagree"** (D), then that would mean you don't like your school for the most part. If you selected **"Strongly Disagree"** (SD) then that would mean that you really hate your school.

Survey #__________________ Sex: Circle One M F Age ____________

Race: ☐ African American (Black) ☐ Hispanic ☐ Caucasian (White)
☐ Native American ☐ Asian ☐ Other (Please Specify)________________

Section 1.	**Strongly Agree**	**Agree**	**Not Sure**	**Disagree**	**Strongly Disagree**
1. I cooperate with other students when doing assignment work.	SA	A	N	D	SD
2. I share my books and resources with other students when doing assignments.	SA	A	N	D	SD
3. When I work in groups in this class, there is teamwork.	SA	A	N	D	SD
4. I work with other students on projects in this class.	SA	A	N	D	SD
5. I learn from other students in this class.	SA	A	N	D	SD
6. I work with other students in this class.	SA	A	N	D	SD

7.	I cooperate with other students on class activities.	SA	A	N	D	SD
8.	Students work with me to achieve class goals.	SA	A	N	D	SD
Section 2.		**Strongly Agree**	**Agree**	**Not Sure**	**Disagree**	**Strongly Disagree**
9.	The teacher takes a personal interest in me.	SA	A	N	D	SD
10.	The teacher goes out of his/her way to help me.	SA	A	N	D	SD
11.	The teacher considers my feelings.	SA	A	N	D	SD
12.	The teacher helps me when I have trouble with the work.	SA	A	N	D	SD
13.	The teacher talks with me.	SA	A	N	D	SD
14.	The teacher is interested in my problems.	SA	A	N	D	SD
15.	The teacher moves about the class to talk with me.	SA	A	N	D	SD
16.	The teacher's questions help me to understand.	SA	A	N	D	SD
Section 3.		**Strongly Agree**	**Agree**	**Not Sure**	**Disagree**	**Strongly Disagree**
17.	I discuss ideas in class.	SA	A	N	D	SD
18.	I give my opinions during class discussions.	SA	A	N	D	SD
19.	The teacher asks me questions.	SA	A	N	D	SD
20.	My ideas and suggestions are used during classroom discussions.	SA	A	N	D	SD
21.	I ask the teacher questions.	SA	A	N	D	SD
22.	I explain my ideas to other students.	SA	A	N	D	SD
23.	Students discuss with me how to go about solving problems.	SA	A	N	D	SD
24.	I am asked to explain how I solve problems.	SA	A	N	D	SD
Section 4.		**Strongly Agree**	**Agree**	**Not Sure**	**Disagree**	**Strongly Disagree**
25.	I carry out investigations to test my ideas.	SA	A	N	D	SD
26.	I am asked to think about the evidence for statements.	SA	A	N	D	SD
27.	I carry out investigations to answer questions coming from discussions.	SA	A	N	D	SD
28.	I explain the meaning of statements, diagrams and graphs.	SA	A	N	D	SD
29.	I carry out investigations to answer questions which puzzle me.	SA	A	N	D	SD

30.	I carry out investigations to answer the teacher's questions.	SA	A	N	D	SD
31.	I find out answers to questions by doing investigations.	SA	A	N	D	SD
32.	I solve problems by using information obtained from my own investigations.	SA	A	N	D	SD

Section 5.		**Strongly Agree**	**Agree**	**Not Sure**	**Disagree**	**Strongly Disagree**
33.	Getting a certain amount of work done is important to me.	SA	A	N	D	SD
34.	I do as much as I set out to do.	SA	A	N	D	SD
35.	I know the goals for this class.	SA	A	N	D	SD
36.	I am ready to start this class on time.	SA	A	N	D	SD
37.	I know what I am trying to accomplish in this class.	SA	A	N	D	SD
38.	I pay attention during this class.	SA	A	N	D	SD
39.	I try to understand the work in this class.	SA	A	N	D	SD
40.	I know how much work I have to do.	SA	A	N	D	SD

Section 6.		**Strongly Agree**	**Agree**	**Not Sure**	**Disagree**	**Strongly Disagree**
41.	I would prefer to find out why something happens by doing an experiment rather than by being told.	SA	A	N	D	SD
42.	I would prefer to do experiments than to read about them.	SA	A	N	D	SD
43.	I would rather do an experiment to find out for myself than listen to other people.	SA	A	N	D	SD
44.	I would prefer to do my own experiments than to find out information from a teacher.	SA	A	N	D	SD
45.	It is better to find it out by doing experiments rather than asking the teacher the answer.	SA	A	N	D	SD
46.	I would rather solve a problem by doing an experiment than be told the answer.	SA	A	N	D	SD
47.	I would rather find out about things by doing an experiment then even asking an expert.	SA	A	N	D	SD
48.	Doing experiments to find out information is better than getting information from teachers.	SA	A	N	D	SD

Section 7.		**Strongly Agree**	**Agree**	**Not Sure**	**Disagree**	**Strongly Disagree**
49.	Science classes are fun.	SA	A	N	D	SD
50.	My school should have more science classes each week.	SA	A	N	D	SD

51.	Science is one of the most interesting subjects in school.	SA	A	N	D	SD
52.	I enjoy going to science classes.	SA	A	N	D	SD
53.	I look forward to science class.	SA	A	N	D	SD
54.	I would enjoy school more if there were more science classes.	SA	A	N	D	SD
55.	The material covered in science classes is interesting.	SA	A	N	D	SD
56.	I like science classes.	SA	A	N	D	SD