Science and Mathematics Education Centre

Evaluation of Inquiry-Based Learning in High School Earth Science and Biology Classrooms: Learning Environment and Attitudes

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DECLARATION

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

Signature:______________________________

Date: January 2015

ABSTRACT

The National Science Education Standards (NSES) has adopted scientific inquiry as a powerful tool that could promote students' understanding of science and create sustainable scientific and technological innovations for future generations. The National Science Teachers Association (NSTA) also recommended that teachers in K–12 classrooms adopt scientific inquiry as the centerpiece of theirdaily science instruction. Therefore, this study particularly focused on evaluating the effectiveness of inquiry-based teaching in terms of high-school students' perceptions of the learning environment and their attitudes towards science.

Data were obtained from 1,396 biology and earth science students, consisting of 735 male students and 661 female students, from 35 classes from three high schools in Los Angeles County public schools. The study design involved comparing an inquiry group with a non-inquiry group. My questionnaire comprised the three scales of Student Cohesiveness, Teacher Support and Involvement from the What Is Happening In this Class? (WIHIC), the three scales of Personal Relevance, Critical Voice and Student Negotiation from the Constructivist Learning Environment Survey (CLES), and the two scales of Attitude to Scientific Inquiry and Enjoyment of Science Lessons from the Test of Science-Related Attitude (TOSRA).

Factor analyses were performed for the 42 learning environment items and for the 30 TOSRA items. Items that met the factor loading criteria of at least 0.40 on their *apriori* scale and lower than 0.40 on all of the other scales were retained. In all, 41 items were retained from the environment scales and 16 items from the attitude scales. The total proportion of variance was 58.12% for the WIHIC scales, 55.10% for the CLES scales and 44.06% for the TOSRA scales. Alpha reliability coefficients ranged from 0.78 to 0.92 for the environment scales and were 0.67 and 0.87 for the attitude scales. Overall, the results strongly supported the factorial validity and internal consistency reliability of my questionnaire scales.

Results of a two-way MANOVA and two-way ANOVAs revealed statistically significant differences between inquiry and non-inquiry classrooms for every learning environment and attitude scale, with effect sizes ranging from 0.22 to 0.93

standard deviations. Instructional-method differences were large in magnitude for Teacher Support (0.93 standard deviations) and Involvement (0.63 standard deviations).When compared with students in non-inquiry-based classrooms, students in inquiry-based classrooms perceived their classroom environments more positively and had higher attitude scores on every scale.

Sex differences were statistically significant for Student Cohesiveness, Teacher Support and Critical Voice, but effect sizes for these scales were small and ranged from only 0.15 to 0.31 standard deviations. For the three scales for which sex differences were statistically significant, female students held somewhat more favorable perceptions than their male counterparts. Sex differences were small and statistically nonsignificant for both attitude scales.

Also, results of a two-way MANOVA were used to examine the interaction between instructional method and sex in order to identify whether instructional-method differences were different or similar for males and females. These results revealed that instruction–by–sex interactions were statistically nonsignificant for the set of all learning environment and attitude scales, suggesting that inquiry-based instruction was equally effective for males and females.

To investigate associations between classroom environments and students' attitudes to science, simple correlation and multiple regression analyses were performed. All six environment scales showed statistically significant correlations with Attitude to Scientific Inquiry and, for Enjoyment of Science, correlations were statistically significant for every learning environment scale except Critical Voice. Inspection of regression coefficients showed that Student Negotiation was a positive independent predictor of Attitude to Scientific Inquiry and that each of the six WIHIC and CLES scales was a positive independent predictor of Enjoyment of Science. Higher learning environment scores were linked to higher Inquiry and Enjoyment scores.

DEDICATION

This thesis is dedicated to:

My late mother

BEATRICE SOPULUCHUKWU EBO

My father

JOSAIAH ODILI EBO

for the sacrifices they made and the prices they paid in ensuring that I receive the best of education

To my wife

BROOKE EBO

And to my three children

CHINONSO JESSE EBO (CJ)

TOCHI JOSAIAH EBO (TJ)

EZEORA JOSHUA EBO (EJ)

for being the best gifts God has given us.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

1.1 Introduction to this Study

Several decades ago, educational researchers focused largely or exclusively on students' achievement, with less emphasis on classroom environment (Fraser, 1989, 1998a). Marzano (1993) proposed that one of the fundamental requirements of learning in the classroom is the establishment of an effective classroom environment. Recently, there has been increasing interest in the investigation of students' and teachers' perceptions of their classroom environment, as well as their relationship to students' outcome (Fraser, 2012). Evaluation of instructional strategies, especially in science, has been a dominant focus for many educational studies during the past decades. Research on classroom environment has evolved through several stages, with almost all past studies reporting a relationship between students' perceptions of their classroom learning environment and learning outcomes (Fraser, 2012; Fraser &Raaflaub, 2013; Khoo & Fraser, 2008). In an attempt to further understand and explore this relationship, this study focused on inquiry-based learning environments and their influence on students' attitudes.

The microcosm of learning ranges from an individual's mental activity, in which knowledge skills, attitudes and ideas are processed (Heidgerken, 1995), to the student's behavior within the classroom and the student's place within the school structure. The aggregate of these multilevel learning structures plays a vital role in the learner's cognitive and psychosocial development. Moos (1998) noted that schools normally adopt structures that determine how students learn and, therefore, classrooms are structured to provide effective platforms for curriculum implementation. Bloom (1974) explained that the summation of the environment surrounding an individual makes up a complex network of forces related to each human characteristic.

Although studies of students' perceptions of their classroom learning environment have been conducted over the past decades, little has been done to help teachers improve their own classrooms (Fraser, 1986; Yarrow, Millwater & Fraser, 1997). In recent times, the emergence of new classroom environment instruments has widened the acceptance of classroom environment research (Rawnsley & Fisher, 1998). The global quest to expand research into new frontiers in classroom environment and the accompanying development of new instruments prompted the focus and foundation of my research. This study focused on inquiry learning from the students' perspectives and how such practices help to improve learning. Fraser (2012) noted that the study of classroom environment is subtle; however, much progress has been made in conceptualizing it, measuring and analyzing it, and in mapping its effects on students.

Inquiry is a learning model that incorporates active students' collaboration that enables learners to generate scientific questions and search for answers through investigative exploration (Haury, 1993). With the growing demand on schools to improve students' academic achievement, coupled with the shift in focus from the traditional teacher-centered perspective to student-centered learning, school districts across the U.S have increased budgetary spending on effective curricula, professional development opportunities for teachers, and the use of technologies and other classroom educational resources. Also Local Education Agencies (LEA) have increased the quest to adopt research-driven and standards-based instructional practices that enhance student outcomes (U.S. Department of Education, 2001).

Although research on classroom environment began several decades ago (Fraser, 1994), teachers and school administrators have recently begun to utilize research data on classroom learning environment. To date, a paradigm shift has taken place in classrooms resulting in the transition from teacher-centered classrooms to student-centered classrooms. Research shows that inquiry-based learning, relative to traditional methods, can enhance students' performance and attitudes about science (Jarret, 1997). The inquiry process is a continuum that engages students in exploratory activities using well-structured investigative processes based on students' ability to apply critical thinking skills in solving scientific problems. As described in Chapter 2, state and federal Departments of Education in the U.S have advocated the use of inquiry learning and the Next Generation Science Standards, drafted during 2011 – 2013 and adopted by the California Department of Education in September 2013, provide detailed guidelines for the implementation of inquiry learning. By adopting inquiry-based learning, students are enriched with the ability to better assess experimental parameters and evaluate data in texts (Wyatt, 2005). According to the National Science Education Standards:

Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop their ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigation, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations and communicating scientific arguments. (National Research Council, 1996, p. 105)

The study of classroom environment has continued to expand over the past 40 years and has been applied to the assessment of the effectiveness of schools' academic programs and to the importance of class/teacher effects in students' learning. Rawnsley and Fisher (1998) noted that researchers have investigated the associations between some classroom environment variables relating to the class/teacher effect and learning outcomes.

Learning environment research over the past four decades has centered mainly on the study of the psychosocial behavior of students and teachers within the learning environment (Fraser,2014). Recently, however, greater emphasis has been placed on improving the classroom social environment (NRC, 1996). Fraser (1981) suggested that teachers should incorporate some elements of the classroom environment in their assessment and evaluation rather than focus solely on achievement. Finch (2001) suggested that the nature of the classroom environment has an influence on students' achievement of their cognitive and attitudinal goals and, therefore, educators should strive to promote supportive and non-threatening learning environments. Socio-cultural values within the classroom environment have also been considered by researchers as a major determinant of students' attitudinal outcomes (Jegede & Okebukola, 1992). Past research has involved the development and the use of instruments to assess the qualities of science classroom environment (Fraser, 1994, 1998a, 1998b, 2012).

As part of the expansion of studies of classroom environments, recent broader acceptance of the importance of classroom environments has led to the emergence of different types of classroom environment instruments for assessing students' perceptions of their classrooms. As part of a sustained effort to monitor the learning progress and transformation of classrooms, two classroom environment instruments pertinent to this study were selected for use: the What Is Happening In this Class? (WIHIC)and Constructivist Learning Environment Survey (CLES). Scales from these instruments were carefully selected for assessing students' perceptions of inquiry learning environments. Also, students' attitudinal outcomes were assessed using the Test Of Science Related Attitudes (TOSRA). The WIHIC and TOSRA are discussed in detail later in this thesis in Sections 2.3 and 2.5 of my literature review and Sections 3.3.2 and 3.3.5 of my research methodology chapter.

This introductory chapter describes the background to my study using the following sections:

Section 1.2 Emergence of the Federal Educational Reform 'Race to the Top'
Section 1.3 Focus on the Next Generation Science Standards: A Place for Inquiry?
Section 1.4 Background of the Research: From the Researcher's Perspective
Section 1.5 Rationale for the Study
Section 1.6 Research Questions
Section 1.7 Significance of the Study
Section 1.8 Theoretical and Conceptual Frameworks
Section 1.9 Overview of the Thesis.

1.2 Emergence of the Federal Educational Reform 'Race to the Top'

A national report on the status of education in the United States, titled *A Nation at Risk* and published by the National Commission on Excellence in Education (1983, p. 9), described American education as "a rising tide of mediocrity":

Our Nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world. This report is concerned with only one of the many causes and dimensions *of the problem, but it is the one that undergirds American prosperity, security, and civility. We report to the American people that while we can take justifiable pride in what our schools and colleges have historically accomplished and contributed to the United States and the well-being of its people, the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people. What was unimaginable a generation ago has begun to occur; others are matching and surpassing our educational attainments.* (National Commission on Excellence in Education, 1983, p. 9)

Education is the strength of every nation. In his publication on the theory of education, Novak (1998) asserts that educational success comes from focusing beyond the learner's domain of thoughts to the feelings and actions of the learner. On this premise, therefore, federal and state educational policies are opening new educational frontiers to identify and accommodate new strategies that would enhance learning proficiency and skills productivity. In March 2010, the United States administration sent to the Congress a blueprint for educational reform for elementary and secondary education called 'Race to the Top', which replaced the previous No Child Left Behind (NCLB) Educational Act. The Race to the Top program marks a historic moment in American education and offers bold incentives to states willing to spur systemic reform to improve teaching and learning in America's schools. The new educational Act ushered in significant changes in the educational system and corrected earlier problems encountered by the previous NCLB educational act by redirecting the learning focus to the growing technological needs in public schools, aligning policies and structures to the goal of college and career readiness. There is a heightened expectation for improved education and the attainment of higher scientific proficiency and greater technological innovation.

Race to the Top is part of the federal government's American Recovery and Reinvestment Act of 2009. It is a competitive grants program that provides monetary incentives to states and school districts to reform their education systems in specific ways. The NCLB law of 2001 mandates various changes in education systems as a condition of receiving continuing funding under Title I. The two programs address overlapping issues. The NCLB provides a foundation for Race to the Top but, because it is voluntary, Race to the Top can stimulate more sophisticated ways of assessing student, teacher and school performance (Lohman, 2010).

The report further revealed that comparative analysis of America's educational standards with other nations, particularly Asia and Europe, showed that science achievement had drastically diminished in the United States, placing the nation in the last seven in science achievement. Recent studies, however, show that there has been improvement in the nation's science education in the past decade as a result of progressive changes made in the science standards, curriculum, instruction and assessment. The previous NCLB Educational Act was widely criticized by educators and researchers because it focused primarily on absolute students' test scores rather than patterns of growth and academic progress. This problem drove many educators and schools administrators to indulge in various forms of malpractice in order to receive federal rewards for academic achievement, thus lowering the standards of education. The NCLB Act was viewed by many as punishment for failure rather than reward for success. To eliminate these problems, the US Department of Education created an educational program called Science, Technology, Engineering and Mathematics (STEM). STEM was designed to provide opportunities for learners to use critical thinking strategies in science and mathematics education and also to support and assist states and local educational agencies in improving science instruction through professional developments programs (www.whitehouse.gov).

Science education over the years has undergone a progressive shift from traditional classroom environments to more student-centered constructivist classroom environments. From a pedagogical point of view, inquiry practices are based on constructivist epistemologies and are commonly known as active learning (Haury, 1993). Constructivists believe that learning takes place because of the changes that occur in human mental frameworks in an attempt to construct new knowledge from prior experiences.

1.3 Focus on the Next Generation Science Standards

Over the past decades, there has been a remarkable degree of flexibility in the educational structures and policies across many states in United States, especially

California. With increasing concerns for attaining domestic equity and international competitiveness, science educators in the state must provide needed assistance that ensures that all learners (including learners with disabilities and those whose primary language is other than English) have equal opportunity to succeed in science education (California Department of Education, 1990). Recent reforms in science education for K–12 public schools in California have widened the focus of science education and mandated reforms that emphasize science learning through inquiry in conformity with the guidelines of the Next Generation Science Standards (NGSS) (California Department of Education, 1990). The new science standards were designed to redirect the focus and resources in an attempt to produce learners capable of competing with the global community in science and technology education. To achieve this goal, the standards rely on inquiry practices that would enable students to conceptualize ideas through questioning and critical thinking components of scientific inquiry and provide students with opportunities to explore their natural environment through scientific investigation. A critical aspect of science learning is the importance of the platform on which learning takes place. Roth, Tobin and Zimmermann (2002) suggested that an interactive learning environment makes a learner an active contributor and participant in the learning process. Such a platform supports creative thinking and problem-solving skills in a well-structured inquiry-based learning environment.

Smith and Ezeife (2010) noted that high school science teachers are aware that the classroom learning environment is an integral part of teaching; instructional changes have an impact on that environment and thus on learning outcomes. The California State Board of Education therefore believes that classroom learning environments must reflect learner's ability to construct new knowledge through the application of inquiry. The state science framework stipulates:

Investigations and experiments engage scientists, catalyzing their highest levels of creativity and producing their most satisfying rewards. The possibility of discovery or of adding new scientific knowledge in the form of facts, concepts, principles, or theories offers a great sense of accomplishment and wonder. Investigation and experimentation can be just as engaging to high school students as they study science. Although students may not discover knowledge new to the scientific community, *they may find pleasure in discovering something new to themselves or in seeing the content from their science text illuminated through demonstrations of the concepts.* (California Department of Education, 2004, p. 278)

A wide array of research has supported the positive effect of inquiry on students' achievement (Haury, 1993; Oliver, 2007; Wolf & Fraser, 2008; Wyatt, 2005). Over the years, inquiry-based learning in science classrooms has been widely accepted and well supported by science educators. To this effect, educators rely on science instruction that is driven by inquiry and for which students enjoy a limitless opportunity to explore their natural environment through investigation. Since the introduction of the new science standards in California, there has been increasing demand on teachers to find ways of improving students' learning outcomes. The State of California science framework provides detailed outlines of the standards, assessment and curriculum requirements for K–12 schools in the state. Research has shown that prompting students to formulate questions and allowing them to work through the problems promote deeper understanding of the content. The requirements contained in the NGSS standards for science education obviously are different from previous practice in which most laboratory activities in high schools were conducted as simple demonstrations, rather than through the lenses of inquiry and constructivist practices. The framework of the New Generation Science Standards is designed on three principal dimensions as shown in Figure 1.1, which identifies the progressive curve of disciplinary core ideas for science learning which are described below:

- *Practices:* This dimension explains behaviors in which scientists engage as they investigate and build models and theories about the natural world requiring skills and knowledge that are specific to each practice. The standards emphasize that engaging students in laboratory investigation processes require skills and knowledge unique to its practice.
- *Crosscutting:* This dimension describes that scientific concepts have applications which cut across and link all domains of science. The NRC emphasizes that learners must know and understand basic scientific concepts that will help to provide an organizational schema for interpreting ideas across different scientific fields.

- *Content:* This dimension describes the idea that disciplinary core ideas have the power to focus K–12 science curriculum, instruction and assessments on the most important aspects of science. According to the science standards, ideas are considered core if they:
  - show broad importance across different fields of science
  - provide resources and tools for higher problem solving
  - are connected to students' real world experiences or societal needs
  - provide skills that are teachable and learnable across grade levels.

Figure 1.1 Model of the Disciplinary Core Ideas in NGSS (Adapted from NGSS, 2013)

The NGSS framework as presented in Figure 1.1has identified inquiry as one of the centerpieces in science education. The framework emphasizes that science learning must involve students in creating new knowledge not only by participating in laboratory investigations, but also by analyzing and explaining the critical components of inquiry processes. In the process, students are provided with the opportunity to independently work through problems by formulating questions that promote deeper understanding of the concepts. The act of science learning goes beyond doing and also involves knowing, which is assessed by one's ability to demonstrate proficiency and mastery of the concept. The NRC (2000) describes proficiency in science as both a body of knowledge and a theory-building enterprise that continually extends, refines, and revises knowledge.

A well-structured inquiry classroom tends to focus on knowledge-based practices that address the ‘why’ questions. According to the Californian Department of Education (1990, 2004), from the research point of view, students with factual knowledge are believed to have the propensity to acquire deeper and wider knowledge using critical-thinking approaches. While traditional direct instruction has its place in a well-defined educational program, research has shown that its effectiveness is limited in providing opportunities and experience for students to actively participate in the learning process (California Department of Education, 1990). Part of the central focus of the NGSS standards is to provide opportunities for learners to develop a wide array of scientific knowledge and pedagogical content skills varying in length, breadth and depth, with a strong conceptual understanding in order to effectively engage in deeper scientific reasoning and higher metacognitive skills.

1.4 Background of the Research: From the Researcher’s Perspective

Educating children is the principal goal of a well-balanced curriculum, especially in science education. Therefore, understanding of the principles and practice of science and its philosophy remain a fundamental part of global science education. Walberg (1969) believes that the industrial and technological standards of any nation depend, to a large extent, on the level of scientific literacy of the population and the development of effective science education programs in schools. Therefore, a scientifically literate person uses science concepts to process skills and values towards making daily decisions as he or she interacts with other people within his or her environment. This process is essential for students to cope successfully and develop the needed skills and knowledge to deal with increasing scientific challenges.

Teachers often face a difficult task in maintaining effective and functional classroom environments. Transfer of knowledge is best achieved when positive relationship exists between learners and teachers. Embedded in this is a classroom environment where teachers are enthusiastic, informed and provided with adequate resources. Stimulating classroom environments can nurture natural curiosity that deepens students’ interests in science learning. Science teachers do not only desire students to pass science tests but also to take the learning of science to heart and pursue careers in science. Studies have shown that learning is best achieved in a classroom where there is a positive relationship between the students and the teacher (Walberg & Anderson, 1968; Fraser & Walberg, 2005; Wubbels & Levy, 1991, 1993). Science-related tasks involving variety and diversity tend to promote learners' interest. Therefore, there is an urgent need for teachers to provide effective learning environments that enhance strong interactions and motivate learning. Central to this need also is having learning environments that provide opportunities that enable students to explore concepts and ideas through inquiry discussions. Therefore, my study was designed to evaluate the effectiveness of inquiry classrooms by assessing students' perceptions of learning environment and attitudes.

Science education in California has changed over time. The emergence of new educational reforms has shifted the dynamics of teaching and learning in Californian public schools. These reforms are part of a rigorous overall strategy to transform science education for all students in order to promote scientific thinking and reasoning. For science education, academic achievement still remains the central focus of educators, as described earlier in Figure 1.1, and achievement is driven by the implementation of disciplinary core standards of practices, content, and cross-cutting diversity. According to California Department of Education (1990):

The most personal message that a science teacher can bring to a student is this: Science is concerned with all of nature, medicine and technology. These concerns are not simply empirical; they are ethical and social. The responsibility of science educators and the function of science curricula are to prepare students for the decision they must make as adults–decisions that daily become increasingly dependent on a clear understanding of science. (p. 14)

Inquiry has become a common practice and standard in most Californian public schools. Some science teachers are uncomfortable and reluctant to use inquiry practices for fear of the inherent discomfort that change might bring or the outcomes that could result from such change. Some teachers claim that inquiry practices are associated with a lot of implementation bottlenecks, consume a lot of time and resources and also make assessment practices very difficult to manage. Bencze

(2009) noted that many science teachers experience difficulty in effectively engaging students throughout the science instructional period. Costensen and Lawson (1986) conducted interviews with inservice traditional biology teachers who were reticent to use inquiry-based instruction in their own classrooms. In order to effectively assess the perceptions and attitudes of students of their enquiry-based classrooms, teachers were encouraged to employ the key principles of inquiry using diverse constructivist approaches during laboratory investigation. Their roles were to facilitate instruction, provide prompts and guidelines for students to generate their own questions, design methods to approach problems and analyze their own data. Teachers ensure that all students are participating and regularly check for understanding and clarification during the investigation process.

1.5 Rationale for the Study

In the past two decades, the principal focus of the Californian science framework has been science content themes. The emphasis on themes is important not only for the teaching of science, but also in the doing of science (California Department of Education, 1990). Today, emphasis has gradually shifted from the mastery of thematic units towards the process of achieving mastery. Although themes in science content still remain the foundation for the design of science activities in Californian public schools, the new standards focus on identifying and describing students' proven behaviors as active learners.Over the years, science programs in California have been formulated and redesigned to improve science education. The evidence of improved science programs is the outcome of students' learning. The California Department of Education framework (1990) established that, in order to evaluate the effectiveness of science programs in the state, such programs must be challenging and stimulating. Students must be engaged in the act of doing science rather than just reading science texts. Teachers, on the other hand, must be able to reflect on how they are teaching and how students are learning science.

Despite the state-wide district plans for science, individual school districts have set plans and programs which align with the state's plan. Effective implementation of these science programs, therefore, involves the active participation of all stakeholders: administrators, teachers, students, parents and the community as a whole. The district's approved science curriculum was designed to guide teachers in using a variety of strategies to facilitate the inquiry process and to increase motivation and learning. The fundamental reason is that, during inquiry, there is an increased student social interaction within the classroom environment (Brewer & Daane, 2002), where students are encouraged to ask questions, share ideas and engage in dialogue. Inquiry requires students to be positively interdependent, so that the benefit to one student benefits the whole group (Colburn, 1998).

1.5.1 My High-School Science Classroom Experience

Looking back at my early days as a high school student in the late 1970s, I remember the ill-equipped science laboratories available for all science lessons. Each science subject had a laboratory (physics, chemistry, and biology) for use by all students in grades 7 to 12. The classroom setting was non-collaborative and science lessons were neither student-friendly nor student-centered. During laboratory sessions, students were given hand-outs showing step-by-step procedures for the investigation and long introductory notes relating to the lesson. Teachers used traditional direct instruction methods with little or no opportunity for students to ask questions or participate in class discussion. The teacher was looked upon as the main source of knowledge. If the teacher did not teach, then it was considered that no learning was taking place. An investigation was considered worthwhile only if it was done according to the teacher's cookbook guidelines and if the results were comparable to the teacher's expectations. In some cases, we would observe the teacher demonstrating laboratory lessons while we took notes and reported our observations.

1.5.2 My Experience as a Teacher

Today, science education has changed. Science programs have gone through progressive reforms not only in California, but also around the world. What used to be a teacher-centered paradigm has shifted towards a more collaborative and constructive process. Throughout my 18 years of teaching service, I have observed gradual and progressive changes in science education. As the State gears up towards implementing the new science education reform act, school districts are making corresponding changes to accommodate the new science program.

For many years, Los Angeles County Office of Education has remained at the forefront for the implementation of the new science standards. In 2011, I was privileged to attend a district-organized professional development programs on Advancement Via Individual Determination (AVID). This program is an aggregate of different rigorous instructional strategies involving the use of writing, inquiry, collaboration and reading (WICR). During one of these meetings, I had the opportunity to speak to a few teachers regarding their perceptions of inquiry lessons as they were presented during the training. The responses from a few teachers were very encouraging. Some of them responded with resounding enthusiasm by suggesting that inquiry was well received, while others were doubtful about the outcomes of inquiry practices because of the students' socio-economic and cultural backgrounds.

Prior to the commencement of this research, I had been involved in a couple of professional development activities for science teachers organized by the school district. During one of these meetings, the emphasis on inquiry, together with the school district's mandate to incorporate inquiry practices in science instruction and teachers' overall responses to the inquiry approach, sparked my interest in inquiry and subsequently my desire to focus my research in this field. To further confirm my interest in conducting research in this field, I decided to observe a few science classrooms where inquiry practices were supposedly practiced; from my observations, it was obvious that all of the classrooms showed a distinctive approach to inquiry. Teachers employed different ways to involve and engage students in the lessons. I also noticed some differences in the amount of rigor involved during discussions and the assessments used. There was disparity in the perceptions of older veteran teachers compared to the younger ones. While older teachers often were reluctant about adopting inquiry-based practices in their classrooms, younger science teachers typically were enthusiastic towards it. Some teachers used outdoor facilities to demonstrate inquiry lessons, such as biology students observing the aquatic ecosystem and earth science students measuring the effect of incoming solar radiation on different surfaces. Other classrooms used simple lessons obtained from the science textbook to engage students in discussion. I also witnessed a few classrooms where students were involved in group discussions and presentations. The integration of multiple summative and performance-based assessments has enhanced inquiry-based classroom environments.

A review of previous studies suggests that inquiry-based classroom environments, where students are actively involved in the learning process by questioning and problem solving using critical thinking approach, promote positive learning outcomes. Therefore my study attempted to evaluate inquiry-based classrooms and investigate the relationship between inquiry learning environments and learning outcomes. In order to effectively answer these questions, my study was narrowed to focus on four research questions delineated in the next section.

1.6 Research Questions

Four principal research questions provide the anchor for this investigation:

1. Is it possible to develop valid and reliable measures of inner-city high-school Biology and Earth Science students':
    a. perceptions of inquiry-based classroom learning environments
    b. attitudes towards science?

2. Is inquiry-based instruction effective in terms of students':
    a. perceptions of learning environment
    b. attitudes towards science?

3. Is inquiry-based instruction differentially effective for male and female students in terms of:
    a. perceptions of learning environment
    b. attitudes towards science?

4. Are there associations between students' perceptions of inquiry-based learning environments and their attitudes towards science?

To answer these research questions, scales from existing learning environment surveys were selected, modified and used for this study. A combination of scales from the original What Is Happening In this Class? (WIHIC) (Fraser, Fisher & McRobbie, 1996)and Constructivist Learning Environment Survey (CLES) (Taylor, Fraser & Fisher, 1997)were adopted and modified to form a new classroom learning environment instrument called the Inquiry-Based Learning Environment Survey (IBLES). The CLES and WIHIC were chosen for this research because of their wide validity, prominence in the assessment of classroom environment, and relevance to my study. Scales from the original Test of Science Related Attitudes (TOSRA), developed by Fraser (1981), also were selected and modified.

1.7 Significance of the Study

Classroom environment studies have provided important knowledge not only for researchers but also for teachers and school district administrators. In United States, for instance, the significance of classroom environment studies is far reaching. States and local education agencies utilize these data to reshape instruction, curriculum and educational resources in order to improve instruction. When students and teachers perceive their classrooms positively, then they demonstrate positive attitudes that enhance learning (Fraser, 1994, 2012). Although many studies have examined students' attitudes and perceptions of their classroom learning environment, very few have been reported for Californian public schools using the CLES and WIHIC. Therefore, my study pioneered research on students' perceptions of inquiry-based science learning environment and their attitudes towards science in inner-city schools of Southern California. It potentially could provide a wealth of information to benefit not only the academic community but also the research community.

As a result of the recent adoption of the New Generation Science Standards by the State of California, science teachers across all grade levels are aware of new ideas that can enhance learning through inquiry. Therefore, another way in which this study is significant is that it is likely to provide needed and specific information for teachers and curriculum designers about data-collection techniques. The data generated from this study could provide investigative tools for teachers and school administrators to use to assess students' attitudes and perceptions of their inquiry-based learning environment.

The outcomes of this research could provide a reflective overview for teachers and administrators for visualizing classrooms from the students' perspectives. Educational research conducted through eyes of the participants often provides an effective mirror for teachers to see themselves and their students. This research is likely to contribute to already-existing research information in the field of learning environments for future use by educators and researchers.

In Chapter 5, further consideration is given to the significance of my study.

1.8 Theoretical and Conceptual Framework

Many contemporary research efforts worldwide now involve the conceptualization, assessment, and investigation of psychosocial aspect of the classroom environment (Fraser, 1998b, 2012). These studies focus on social characteristics involving human behavior within the learning environment. Because inquiry teaching involves not only data collection, analysis and interpretation but also the process of providing reasonable answers to critical scientific questions, from a pedagogical perspective, it reflects the characteristics of the constructivist model. Bruner (1966) describes the constructivist model as an active learning process in which learners construct new ideas or concepts based upon their current/past knowledge. The learner chooses, evaluates and transforms information, constructs hypotheses, makes decisions, and relies on a cognitive structure (i.e., schema, mental models) to provide meaning. Huitt (2009) summarized the characteristics of effective instruction which emerged from his theoretical constructs:

1. Instruction should relate to learners' predisposition to facilitate interest toward learning and must be connected with experiences and contexts that make the student motivated and able to learn (readiness).
2. Content structure and instruction must be simplistically presented so that they can be understood by the learner (spiral organization).
3. Instruction should be designed to facilitate extrapolation of ideas and filling in the gaps (going beyond the information given).

For several decades, constructivism has become the dominant model in science classrooms and the leading theoretical framework in educational psychology and scientific research across nations (Mayer, 2004; Tobin, 1993). Constructivism is widely described by educators as active learning. Interestingly, constructivism provides a plausible, functional framework for understanding natural experiences obtained from acquiring learning. Eick and Reed (2002) maintained that inquiry-based classroom environments provide a holistic epistemology that integrates diverse auditory, visual, tactile and kinesthetic learning devices, as well as concrete and abstract components needed in cognitive and meta-cognitive exercises. With inquiry-based learning, teaching skills become ultimately crucial in facilitating the inquisitive minds of learners and prompting them to utilize their abilities and prior knowledge to construct new ideas. To effectively implement inquiry-based practices in classrooms, teachers usually depend on their individual goal orientation, interactive and collaborative strengths with the students and pedagogical knowledge and teaching experiences (Eick & Reed, 2002).

A crucial challenge in science teaching is to create learning experiences that actively engage learners and support, explain, evaluate, communicate, and apply skills needed to make sense of these experiences. Fraser (1986) maintains that classroom environments involved the shared perceptions of the students and teachers in their classroom environment. In describing the quality of classroom environments, Fraser (1989) observed that students spend a great deal of time (about 15,000 hours) in school classrooms and therefore that the quality of classroom environment has great relevance to their learning. Huitt (2009) proposed many different approaches to improving learning in the classroom, including looking for different ways to engage individual students, developing rich environments for exploration, preparing coherent problem sets and challenges that focus the model building effort, and eliciting and communicating student perceptions and interpretations. Constructivist models postulate that learning is a cognitive process in which students' critical thinking and problem-solving skills are enhanced as they attempt to make sense of their thought process through self-application of competence and independent inquiry (Sobat, 2003; Young, 2005).

Studies of the concepts and application of constructivism in science classrooms are well documented in the literatures (Cannon, 1995;Johnson & McClure, 2000, 2004; Maor & Fraser, 1996; Maor& Taylor 1995; Nix, Fraser & Ledbetter, 2005; Oliver, 2007;Taylor, Fraser & Fisher, 1997). Maor and Taylor (1995) and Maor and Fraser (1996) noted that constructivism is a social process in which learners are engaged in the construction of new knowledge using prior experiences. In their review of past research, Maor and Taylor (1995) identified the social environment in which learners interact socially to engage in meaningful construction. In investigating and assessing inquiry-based classrooms environments, the focus is how constructivist activities translate into constructivist learning, which is perceived as an active process in which learners are actively involved in the learning process (Mayer, 2004). Tobin (1993) concluded that constructivist theory has become widely accepted in educational research. My study was designed using a framework of critical constructivism and social constructivism. The postpositivist model also influenced the framework of this study. Figure 1.2 describes a model, that formed the framework for this research, which identifies two theoretical branches of constructivist epistemology used in this research: critical and social constructivism. A principal commonality that exists between the two ideologies is the use of communicative language.

In order to effectively assess inquiry-based classroom environments, a closer examination was made of the behaviors of learners and teachers in observing and identifying salient constructivist practices such as: the nature and level of interaction that takes place through collaborative communication; student involvement and level of participation in the learning process; and, most importantly, the level of independence that the learner exercises in the learning process. These and other questions provided the skeletal framework for the design of this research.

1.8.1 Positivism and Postpositivism

Anderson (1998) identified two dominant and distinctive research paradigms predominantly used in academic research: the positivist paradigm and postpositivist paradigm. The former is based on the principle that ideas and concepts must portray logical validity and truth, if they can be observed and verified. This research paradigm follows the process of quantitative analysis of natural patterns, behaviors and responses that center on individual values and observations. The postpositivist paradigm, on the other hand, integrates human perspectives and individual conceptual ideas into the understanding of certain natural phenomena. This approach anchors on the researchers in their natural environments. Researchers have argued the significance of postpositivism on the viewpoint that qualitative research has elevated contemporary understanding of scientific inquiry (Clark, 1998).

Anderson (1998) believes that thepostpositivist model involves the integration of human perspectives and individual conceptual ideas that bring about understanding of natural phenomena,which can be contrasted with positivism which is presented with the empirical methods of quantitative research. He further suggested that postpositivism is a holistic paradigm that integrates qualitative research with the use of questionnaires while, at the same time, maintaining the natural setting of the target population. Clark (1998) considers that, although empirical methods can be shaped by positivistic philosophy, it is increasingly being recognized that empirical work can alternatively be based on a postpositivistic philosophy which avoids many of the inadequacies associated with the positivist model. Importantly, under postpositivistic philosophy, the perceptions of the researcher are not seen as being wholly detached from the inquiry. Because my study focused primarily on quantitative data-collection methods involving questionnaires, the postpositivist method was selected for this study.

1.8.2 Social Constructivism

Social constructivists view learning as a social construct that is derived from social activity and that enables learners to understand and manage their social reality (Mandeville & Menchaca, 1991). This theory focuses mainly on the language and meaning that are gained through communication between individuals within the environment (Gergen, 1995). Harlen (2010) explained that social constructivism involves sharing, discussing and defending ideas, dialogues and reflections, recognizing the impact of other ideas on the way in which learners make sense of things, and the importance of language. Teaching strategies using social constructivism as a referent include teaching in contexts that might be personally meaningful to students, negotiating taken-as-shared meanings with students, class discussion, small-group collaboration, and valuing meaningful activity over correct answers (Wood et al., 1995). Atwater (1996) posited that, in a social constructivist classroom environment, science learners acquire knowledge when their inner states reflect or represent the existing state of the external scientific world. In a social constructivist environment, learners are directly influenced by the people around them, such as teachers, friends, students, administrators, and participants.

Social constructivist classrooms engage students in active learning processes and create relationships that affect what students learn within the classroom domain. Tobin (1993) maintains that social constructivism recognizes that knowledge is personally constructed, and insists that cultural experiences and interactions with others in social settings mediate each individual's constructions of meaning. Science learning takes place when there is social interaction among the learners. However, Millar and Driver (1987) believe that the presence of the individual mind plays a significant role as learners view science knowledge as a personal and social construct. Because social constructivists believe that individuals construct knowledge through social involvement and participation in classroom discourse (Taylor, 1994a), creating learning environments that support discussions promote social constructivism. The theory of development formulated by Vygotsky, in association with the application of language development which incorporates the benefits derived from collaboration and social interaction, lends credence to the social constructivist theory. Maor and Taylor (1995) suggested that social constructivism involves a social activity in which learners engage in meaningful knowledge construction through peer discussions and teacher-facilitated discussions. Social constructivists believe that their social interactions and culturally-organized classroom environments facilitate students' learning. The design of this research identified some characteristics from the social constructivist framework that provided the setting for this research.

1.8.3 Critical Constructivism

The fundamental feature of critical constructivism is the promotion of communicative ethics, through dialogue towards establishing mutual understanding. The theory identifies the importance that language plays in communication, and therefore views constructivism within a social and cultural environment. Gergen (1995) perceived the classroom as an entity for which socio-cultural realities are constructed through collaborations and communicative interactions between the learners and the teacher. Taylor (1996) describes critical constructivism as a social epistemology that addresses the socio-cultural context of knowledge construction and serves as a referent for cultural reform. Taylor and Fraser (1991) developed the original version of the Constructivist Learning Environment Survey (CLES) to assess the extent to which a learning environment is consistent with constructivist epistemology. Taylor, Fraser and Fisher (1997) later used the early version of the revised CLES in two classroom-based, collaborative, small-scale, qualitative studies to gain insight into the conceptual soundness and psychometric structure of the CLES. However, they discovered that this version of CLES did not take into cognizance the importance of the cultural context within the classroom environment as advocated by proponents of critical constructivism. Therefore, Taylor et al. (1997) identified the cultural myths that tend to inhibit the development of constructivist classrooms and modified the original CLES in order to accommodate critical learning perspectives and add a cultural dimension as a referent.

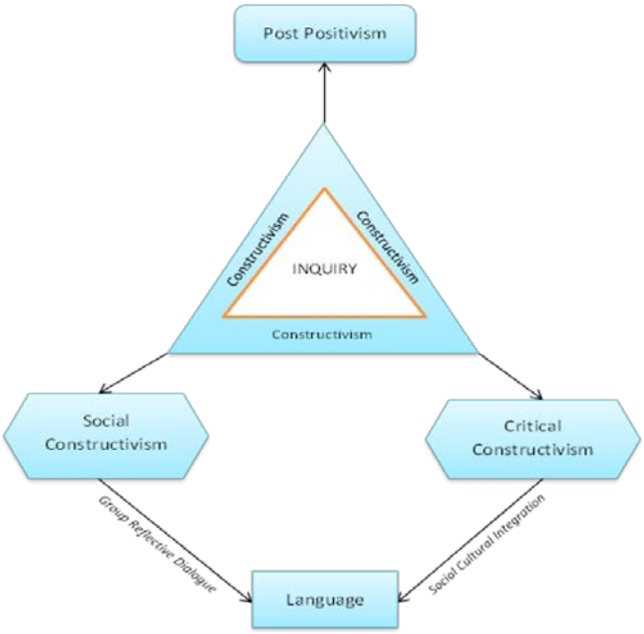

Figure 1.2 Flowchart of the Framework for This Research

Communication between students and the teacher was the fundamental goal in the development of the revised CLES. Geelan (1997) believes that critical constructivism involves a process of teaching and learning that is socially constructed, and therefore involves some inherent repressive myths, such as cold reason and hard control, that can lead to poor development of constructivist classrooms. Taylor et al. (1997) noted that this conceptual change research identifies two fundamental roles: the important role that students' prior knowledge plays in the development of new conceptual understandings; and the reflective process of interpersonal negotiation of meaning within the consensual domain of the classroom community.

Fok and Watkin (2006) reported a study that successfully investigated the impact of the introduction of critical constructivist teaching on higher-achieving students. The study showed that higher-ability students changed to meaning-oriented learning motivation and strategies compared with students in the lower-ability class. Awareness of the nature of the new learning environment was related to this shift to a deeper-level approach in learning. My study therefore was based on the premise of both critical constructivist theory and the social constructivist approach. The instrument used in my study was based on scales selected from the modified CLES (Taylor, Fraser & Fisher, 1997) combined with scales selected from What Is Happening In this Class? (WIHIC) (Fraser, Fisher & McRobbie, 1996).

1.9 Overview of the Thesis

This thesis reports an investigation that aimed to validate an instrument for assessing students’ perceptions of their inquiry-based classroom environments called the Inquiry-based Learning Environment Survey (IBLES). The instrument is based on scales selected from What Is Happening In this Class? (WIHIC) (Fraser, Fisher & McRobbie, 1996) and Constructivist Learning Environment Survey (CLES) (Taylor, Fraser & Fisher, 1997). I also assessed students’ attitudes towards science using the Test of Science Related Attitudes (TOSRA). This investigation also involved associations between students’ perceptions of the classroom learning environment and their attitudes. The main aim of my study focused on the evaluation of inquiry-based science teaching in terms of high-school students’ perceptions of science classroom environment and their attitudes towards science.

Chapter 1: The introductory chapter presented background information about the research. It also provided insight into the development of the new science standards and the adoption of federal and state educational reforms. This chapter also identified the research questions and the significance of the research, as well as introducing the research framework.

Chapter 2: This chapter reviews literature pertinent to the study in four sections. The first section provides a historical perspective on classroom environment studies. The second section reviews classroom environment instruments and their origin, development, and uses in past research. The third section discusses the assessment of perceptions of teacher–student interpersonal behavior and also explores past studies of the perceptions of different sex subgroups, grade-level variations, and associations with academic achievement. The fourth section reviews past literatures on the conceptual framework of inquiry and associations between inquiry-based learning environments and students' attitudes. This section also reviews the adoption of Next Generation Science Standards and the application of inquiry-based learning in contemporary science education in the United States.

Chapter 3: This chapter describes the methods used for this study, including the collection of data from 1,396 students using questionnaires. This section also discusses the development and selection of the scales for inclusion in the Inquiry-Based Learning Environment Survey (IBLES) and scales from the Test of Science Related Attitudes (TOSRA) to assess students' attitudes to science. Data-collection methods are also discussed along with data-analysis methods and the interpretation of results.

Chapter 4: This chapter describes the analyses of data obtained from 1,396 high-school science students in Californian public schools using the IBLES. These data analyses addressed my four research questions and yielded results that are reported in this chapter. Firstly, is it possible to develop valid and reliable measures of science students' perceptions of the classroom learning environment and their attitudes towards science? Secondly, is inquiry-based instruction effective in terms of students' perceptions of learning environment and attitudes towards science? Thirdly, is inquiry-based instruction differentially effective for male and female students in terms of perceptions of learning environment and attitudes towards science? Fourthly, are there associations between students' perceptions of inquiry-based learning environments and their attitudes towards science?

Chapter 5: This chapter draws on the previous chapters to provide a summary and discussion of the major findings from the quantitative data analysis. The chapter describes the significance and implications of this study and identifies major constraints and limitations encountered. The chapter concludes by providing suggestions and recommendations for further classroom environment research associated with inquiry-based instruction.

Chapter 2

LITERATURE REVIEW

2.1 Introduction and Overview

Several decades ago, educators and researchers depended almost exclusively on students' achievement as the criterion in curriculum evaluation, with much less emphasis on the classroom environment (Fraser, 1998a, 1999, 2012). Recently, however, there has been increasing interest in the conceptualization, assessment, and investigation of students' perceptions of the psychosocial characteristics of their classroom environments and the relationship it has with students' affective and cognitive outcomes (Fraser, 1998a, 1998b; Goh & Khine, 2002). Many changes have taken place over the past couple of decades in the focus of investigations of learning environments, with dimensions increasingly becoming diversified and complex (Dorman, 2002) and reflecting constructivist instructional approaches (Fraser, 2001). Dorman (2002) defined the concept of environment in the educational setting as the atmosphere, ambience, tone or climate that pervades a particular setting. A long time ago, Dewey (1938) provided a compelling definition of environment as "whatever conditions interact with personal needs, desires, purposes, and capacities to create the experience which it had" (p. 42). Fraser (1998, p.   ) claimed that the learning environment can refer to the "social, physical, psychological, and pedagogical contexts in which learning occurs and which affects student achievement and attitudes". Therefore, understanding the complexity of learning environments requires identification of various dimensions that collectively interplay for effective learning to take place.

Educational reformers are currently shifting interest towards creating learning environments that are more student-centered (Schneider, Krajcik & Blumenfeld, 2005) and that provide opportunities for positive interactions and discovery learning. Hurst (1996) suggests that active and collaborative science instruction is an effective and efficient way to promote learning and to develop understanding among learners and teachers. Although quite a number of studies have examined different factors that affect students' perceptions and attitudes, and thus learning outcomes, my study was primarily designed to evaluate the effectiveness of inquiry-based instruction.

Classroom environment involves the physical, social, and emotional interactions between students as well as between teachers and students (Dorman, 2002). Past reviews of literature (Fraser, 1998a, 1998b, 2012) show that there is a consistent and positive relationship between classroom environment and students' outcomes. Research has established that academic achievement not only depends on curriculum, instruction, content, pedagogy, and assessment, but also on how students perceive their classroom environments (Fraser, 2001), as well as the quality of interactive relationship between teachers and students throughout the learning process. Therefore, students' responses towards their learning environments, in addition to other factors such as teacher support, learning expectations, and quality-based, student-centered instructional practices, stand out as underlying influences on learning outcomes (Akey, 2006). A normal and well-structured classroom environment provides an adequate channel for monitoring, evaluating and enhancing instruction, as well as for improving the general classroom climate. Puacharearn and Fisher (2004) assert that the fundamental key to improving student achievement and promoting positive attitudes is to create classroom environments that provide active student involvement and good interpersonal relationship.

The shift from traditional teacher-centered classrooms to more student-centered orientations has sparked research into evaluating the impact of student-centered classroom environments. Remarkable progress has been made in the conceptualization, assessment and investigation of classroom learning environments (Aldridge, Fraser & Huang, 1999) using multiple research methods involving qualitative and quantitative approach as advocated by Fraser and Tobin (1991), Tobin and Fraser (1998) and Aldridge, Fraser and Huang (1999). An integrated system of qualitative and quantitative classroom environment research, through the use of multiple theoretical perspectives and constructs designed to frame students' and teachers' perceptions of their experienced and preferred learning environment, have proved increasingly rewarding (Tobin & Fraser, 1998).

A wide array of studies has been undertaken by researchers into the successes, problems, prospects, and interrelationships among stakeholders and the debilitating factors that limit the efficacy of classroom learning environments, as well as the implications of students' perceptual views for learning within their social environment (Akey, 2006; den Brok, Fisher, Rickards, & Bull, 2005; Fraser, 2001, 2012; Hurst, 1996; Patrick & Ryan, 2003). Students' outcomes consistently have been found to be better when students perceive the classroom environment to be positive and supportive (Fraser, 2014). This suggests that the quality of classroom interaction, coordination, and involvement between students and teachers in the pursuit of knowledge and understanding, among other things, define the quality of learning taking place in the classroom (Patrick & Ryan, 2003). This concept supports Dewey's (1916) view that effective learning requires social interaction among students and therefore that new knowledge is constructed when learning is made meaningful to the learner (Mvududu, 2003). Fraser (1998a) noted that past research on students' perceptions of learning environments primarily has had four major foci: associations between students' outcomes and perceptions of the classroom environment; differences between teachers' and students' perceptions; whether students perform better in their preferred classroom environment; and evaluating curricula in terms of their impact on the classroom environment.

Learning is promoted in social, interactive and student-centered classroom environments that place the responsibility for learning on the learner (Patrick & Ryan, 2003). Self-regulated learning environments (Patrick & Ryan, 2003), integrated with proactive student involvement and diverse learning strategies that engage mental processes, are likely to lead to better academic achievement (Young, 2005). Akey (2006) maintained that numerous studies have supported that students' engagement and collaboration remain the fundamental factors that enhance knowledge acquisition and retention. The central focus of education is to enhance the acquisition of knowledge and skills through classroom interaction between teacher and students. In so doing, Roth, Tobin and Zimmermann (2002) consider that, in interactive learning environments (activity theory), learners are active creators rather than passive reactors in the learning process. Further, Fraser (1998b) recognized the impact of students' perceptions of classroom environment on their affective and cognitive outcomes. Baek and Choi (2002) considered the extension of classroom studies to include the assessment of students' interpersonal and intrapersonal behavior as it relates to their perceptions of their learning environment.

This chapter reviews literature pertinent to my study of inquiry-based science learning environments using the following organization:

2.2 Perspectives on Classroom Environment Research

A vital aspect of classroom learning environment research is the investigation of its impact on the learner and the teacher. Although numerous studies have been conducted into assessing classroom learning environment internationally, only a few of these studies have provided meaningful assistance for teachers and local education agencies in effectively monitoring and changing classroom learning environments (Fraser, 2012). Evidence that supports the impact of positive classroom environments on student outcomes is well documented in literature (Fisher & Khine, 2006; Fraser, 1998b; McRobbie & Fraser, 1993). In Asia, the study of learning environments has been undertaken in Brunei (Scott & Fisher, 2004), Indonesia (Fraser, Aldridge & Adolphe, 2010), Taiwan (Aldridge, Fraser & Huang, 1999), Singapore (Khoo & Fraser, 2008; Wong & Fraser, 1996), Japan (Hirata & Sako, 1998), India (Koul & Fisher, 2005), Korea (Baek & Choi, 2002; Kim, Fisher & Fraser, 2000; Lee, Fraser & Fisher, 2004) and Thailand (Puacharearn, 2004).

The foundations of classroom environment research began as far back as the late 1920s with the pioneering work of Hartshorne and May (Walker, 2004). On this foundation, other prominent research on classroom environment was built. Lewin's (1936) field theory defined behavior as a function of the person and the environment. In his field theory of learning environment, Lewin (1936) developed the behavior–environment formula, $B=f(P, E)$ where the behavior factor (B) is a function of (f) the person (P) and the environment (E). Lewin recognized that both the environment and its interactions with the personal characteristics of that individual are potent determinants of human behavior. The theoretical perspective that began with the early research on school climate and classroom environment was pioneered by the early work of Murray (1938), who reviewed Lewin's field theory and extended the concept of human behavior to the development of a *need-press* theory. This theory, according to Murray, conceptualizes a person in terms of his/her psychological needs and the environment in terms of its press. Jackson (1988) pointed out that the distinguishing feature in the Lewinian approach was the translation of scientific concepts and analysis into experimental operations and interpretations.

In reviewing the work of Murray, Moos (1968) developed a number of social climate scales, including those for use in correctional institutions and psychiatric hospitals. Moos (1979) conceptualized that social climate has attributes of personality and human characteristics which can be described as warm, receptive and supportive, or cold, rigid and restrictive. Trickett and Moos (1973) expanded the domain of classroom environment research to include students' learning behavior and attitudinal responses within their psychosocial environment. Moos (1979) further developed a social ecological approach for the assessment of classroom learning environment, proposing that social climate ultimately reflects consensual perceptions of the social environment of the school or classrooms. Fraser and Fisher (1982) made a connection between students' social climate and outcome variables. Felner et al. (2007) suggested that various dimensions of school climate have a direct relationship with differences in the size, structure, and activities of interdisciplinary teams among learners, as well as with the interplay of other factors that affect school climate, such as classroom instructional practices, teacher attitudes and readiness, teacher–student interaction and students' motivation.

Contributors to the field of learning environment research often attribute the beginning of research in this field to the early pioneering independent contributions of two American researchers, Herbert Walberg and Rudolf Moos, over 40 years ago (Fraser & Walberg, 2005). The Learning Environment Inventory (LEI) and Classroom Environment Scale (CES) were the offspring, developed out of the efforts of these two scholars in the late 1960s. These early instruments were designed to assess the behavior and perceptions of students in their classroom psychosocial environments. The initial development of LEI began in 1968, as part of the research and evaluation of Harvard Physics Project (HPP). The project, which was aimed at providing teachers with the needed tools for effective physics instruction in realistic classroom environments, involved an investigation of secondary-school physics students in United States (Walberg & Anderson, 1968). This project paved the way for the development and use of the Learning Environment Inventory (LEI).

A sizeable number of studies have investigated students' attitudes and their perceptions of the learning environment across all educational levels (Fraser, 1994, 2012). While numerous investigations focused on the development and validity of classroom learning environment instruments and evaluations of educational innovations (den Brok, Fisher, Rickards, & Bull 2005; Finch, 2002; Fraser, 1998b), other instruments were developed to answer other salient classroom environment questions such as: How does classroom environment affect students' learning, attitudes, and outcomes? How can teachers assess their own classroom environments and make improvements? What differences exist between preferred and actual classroom environments? How is classroom environment affected by curriculum changes (Fraser, 2001)? Byrne, Hattie & Fraser (1986) suggested that an ideal learning environment must be conducive and supportive for learning. Many students perceive the classroom as a whole differently from their perceptions of their personal role within the classroom (Fraser, Fisher, & McRobbie, 1996). Fraser (1998b, 1999) concluded that there is a strong relationship between students' learning outcomes and the learning environment. This relationship has remained the strongest focus of educational research involving learning environments (Quek, Wong & Fraser, 2002). Fraser and Fisher (1983a) believe that previous classroom environment research gained its credence from its ability to predict students' cognitive and affective outcomes based on their perceptions of their classroom learning environments.

Investigations of classroom environments using multiple research methods involving qualitative and quantitative approaches are discussed by Tobin and Fraser (1991), Fraser and Tobin (1998) and Aldridge, Fraser and Huang (1999). An integrated system of qualitative and quantitative classroom environment research, through the use of multiple theoretical perspectives and constructs designed to frame students' and teachers' perceptions of their experienced and preferred learning environment have proved increasingly rewarding (Tobin & Fraser, 1998). Jiusto and DiBiaso

(2006) added that the use of qualitative methods, such as interviews, observations, and ethnographic techniques, can provide a more detailed and extensive understanding of students' learning. Fraser (1998a) believes that learning is a direct function of students' learning exposure within their classroom environment. He argued that students acquire increasing experience with time and, therefore, can adequately define their perceptions of that learning environment.

Patrick and Ryan (2003), however, suggested that such classroom social environments must reflect positive interactions that promote mutual respect and students' task-related interactions, as well as showing good teacher support. Studies of science and mathematics classroom environments have shown that students' perceptions of their learning environment contribute to their learning outcomes (den Brok et al., 2005). Patrick and Ryan (2003) consider that motivated learning hinges on self-regulated and student-centered classroom environments and their ability to calve a niche that effectively utilizes social interactions for achievement purposes within that learning environment. Young (2005) suggested that proactive learning takes place when students' active involvement demonstrates metacognitive and mental skills that eventually lead to better academic achievement.

2.3 Classroom Environment Instruments

The study of learning environment is an important branch of educational research and some school reforms have been driven by the outcomes of classroom environment research. To understand the nature and operation of classroom environments, it is important to have a microscopic view of the relationships and interactions that exist between teachers and students within their classrooms. Attempts to operationalize classroom environment in terms of the perceptions of teachers and students have proved to be beneficial (Fraser, 1998a). Fraser (2012) has identified some of the most prominent classroom environment instruments for use by middle- and high-school student: Classroom Environment Scale (CES) (Moos & Trickett, 1973), Learning Environment Inventory (LEI) (Fraser, Anderson & Walberg, 1982), My Class Inventory (MCI) (Fisher & Fraser, 1981), Science Laboratory Environment Inventory (SLEI) (Wong & Fraser 1995), Constructivist Learning Environment Survey (CLES) (Taylor, Fraser & Fisher, 1977), What Is

Happening In this Class? (WIHIC) (Fraser, Fisher & McRobbie, 1996), and Questionnaire on Teacher Interaction (QTI) (Wubbels & Levy, 1991).

Table 2.1, adapted from Fraser (2012), lists each scale in the eight instruments. The second column of the Table 2.1 shows the educational level for which the instrument was designed (e.g. primary, secondary, higher education). The third column shows the number of items contained in each scale, while the last three columns show the name and classification of each scale according to Moos's (1974) scheme for classifying human environments. The three basic types of dimensions described by Moos are Relationship Dimensions (which identify the nature and intensity of personal relationships within the environment and assess the extent to which people are involved in the environment and support and help each other), Personal Development Dimensions (which assess basic directions along which personal growth and self-enhancement tend to occur) and System Maintenance and System Change Dimensions (which involve the extent to which the environment is orderly, clear expectations, maintains control and responsive to change). Literature about each of the questionnaires is reviewed below.

2.3.1 Classroom Environment Scale (CES)

Trickett and Moos (1973) published the first version of the Classroom Environment Scale (CES) for the assessment of high-school classroom environments. The instrument became popular and widely-used during the 1970s. Moos and Trickett (1974) developed the CES to assess teacher behavior, teacher–student interactions and student–student interactions. Over 20 years, these researchers focused on community psychology and classroom environments and generating theoretical models to understand social relationship among learners (Trickett, Leone, Fink, Molden, & Braaten, 1993). The original CES is a 90-item, forced-choice instrument that assesses nine different dimensions grouped in three broad domains of classroom experience: (a) Interpersonal Relationships, (b) Goal Orientation, and (c) System Maintenance and Change. Like the other social climate scales, the CES had been shown to possess adequate reliability and validity.

Fisher and Fraser (1983a, 1983b) studied relationships between student affective and cognitive learning outcomes and their perceptions of classroom environment as measured by the Classroom Environment Scale (CES). Findings based on 1,083 students in 116 science classrooms were that each CES scale displayed satisfactory internal consistency and discriminant validity, as well as there being significant differences between the perceptions of students in different classrooms.

Fraser and Tobin (1991) adapted a short form of CES for investigating students' perceptions of their classroom environment in a study involving 8th grade science students. The modified instrument has the six dimensions of Involvement, Affiliation, Teacher Support, Task Orientation, Order and Organization, and Rule Clarity. The validity of this instrument was checked with data collected from 15 classroom teachers (12 male and three female science teachers) from two coeducational high schools. Qualitative data were collected through observation of science teaching in grade 8, 9 and 11 classrooms. Interactions in most of the classrooms were found to be mainly teacher-dominated with these teachers caring relatively little about providing optimal interactions among students during teaching.

Fraser and Fisher (1983a) used the Classroom Environment Scale (CES) in investigating the influence of person–environment fit on students' achievement. The study investigated whether students achieved more when in their preferred classroom environment. A total of2,175 students' responses were collected from eighth and ninth grade science classes in Tasmania, Australia using the CES in association with the Test of Enquiry Skills (Fraser, 1979) and Test of Science Related Attitudes (Fraser, 1981). The research showed that students' achievement and attitude scores were higher when there was more congruence between the actual classroom environment and that preferred by students (Fraser & Fisher, 1983b).

Trickett et al. (1993) adapted the original version of CES developed by Trickett and Moos (1973) to assess special-education classrooms. The scales were revised to make then suitable for special-education classrooms and to be suitable for assessing the perceptions of special-education students across different curricula. Also, the scales were revised to evaluate the effect of course content, teaching methods, teacher personality, class composition and characteristics of the overall classroom environment. Students with diverse behavioral disorders and emotional disturbance from 79 special-education classrooms in 16 residential and day schools were selected for the study. Analyses showed that only seven of the nine aspects of the classroom found in the original CES were reliably reported in special-education classrooms. The study validated the revised version of the CES for use not only in traditional public school classrooms, but also for use in special-education classes in residential and day settings.

Table 2.1 Overview of Scales Contained in 8 Commonly-Used Classroom Environment Instruments (LEI, CES, MCI, QTI, SLEI, CLES, WIHIC, and TROFLEI)

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 Favoritism Cliqueness Satisfaction Apathy	Speed Difficulty Competitiveness	Diversity Formality Material Environment Goal Direction Disorganization Democracy
Classroom Environment Scale (CES)	Secondary	10	Involvement Affiliation Teacher Support	Task Orientation Competition	Order and Organization Rule Clarity Teacher Control Innovation
My Class Inventory (MCI)	Elementary	6--9	Cohesiveness Friction Satisfaction	Difficulty Competitiveness	
Questionnaire on Teacher Interaction (QTI)	Secondary/ Primary	8--10	Helpful/Friendly Understanding Leadership Student Responsibility and Freedom Dissatisfied Admonishing Uncertain Strict		
Science Laboratory Environment Inventory (SLEI)	Upper Secondary/ Higher Ed	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 Outcome-Focused Learning Environment Inventory(TROFLEI)	Elementary/ Secondary	8	Student Cohesiveness Teacher Support Involvement	Investigation Task Orientation Cooperation	Computer Usage Equity

Adapted from Fraser (2012)

Bartholomay (1996) used a modified version of CES called the Adult Classroom Environment Scale (ACES) to investigate adult classrooms. The study, conducted in nine community colleges in Virginia, focused on the perceptions of students and teachers of developmental studies classroom environments, as well as students' opinions about the ideal classroom environment. The study involved three phases. Firstly, 2,238 students were randomly selected from nine community college campuses. Secondly, the sampled students were placed into four groups of identical sizes. Thirdly, these groups were stratified into interdisciplinary subgroups. The author concluded that students tend to prefer ideal classroom environments where they are actively involved in the learning process and have more interactions with each other and with their instructors.

2.3.2 Learning Environment Inventory (LEI)

Prominent among the pioneering research instruments is the Learning Environment Inventory (LEI) that was developed as part of the research program of Harvard Project Physics. Previous studies with the LEI have established the significance of assessing school and classroom social climate especially for researchers and educators (Brand, 2011). The LEI has been used to measure the social climate of learning in the classroom as perceived by students. The original form of the LEI contained the 15 scales of Cohesiveness, Diversity, Formality, Speed, Environment, Friction, Goal Direction, Favoritism, Cliqueness, Satisfaction, Disorganization, Difficulty, Apathy, Democracy, and Competitiveness (Walberg, 1969). To determine the validity of the LEI, Byrne et al. (1986) analyzed data collected from 1,675 students in 18 schools in New South Wales, Australia. Students were administered the preferred and the actual versions of LEI. The findings replicated previous results with all of the assessed environment scales showing high reliability and a significant association emerging between student achievement and classroom environment factors. Anderson (1970) validated the LEI in a study conducted in Canada involving 1,600 grade 10 and 11 students in Montreal. The study replicated previous findings, established strong validity and reliability, and confirmed that student perceptions of classroom environment were a potent determinant of learning outcomes.

Results from an extensive meta-analysis performed by Haertel, Walberg, and Haertel (1981) showed that learning outcomes were related positively to perceptions of difficulty, cohesiveness, formality, democracy, and satisfaction, but negatively associated with friction.

2.3.3 My Class Inventory (MCI)

The My Class Inventory is a simplified version of Learning Environment Inventory (LEI) designed for use with 8–12 years-old students (Fisher & Fraser, 1981; Fraser, Anderson, & Walberg 1982). A short form, containing 25 dichotomously-scored items, has been developed (Fraser & Fisher, 1983a). The questionnaire has two versions, an Actual Form and a Preferred Form. Several studies have validated the use of MCI at the primary-school level (Fraser et al., 1982; Scott Houston, Fraser, & Ledbetter, 2008). Fisher and Fraser (1981) and Fraser et al. (1982) believe that elementary school teachers are likely to be interested in the My Class Inventory for use with their students because it describes the classroom environment through the following five dimensions: Cohesiveness, Competition, Difficulty, Friction, and Satisfaction. These five dimensions have been shown to have strong relationship to student learning outcomes (Goh, Young & Fraser, 1995).

Scott Houston et al. (2008) investigated the perceptions of 588 students selected from 28 grade 3–5 classrooms with the MCI in order to evaluate the effectiveness of the use of textbooks, science kits, and the combination of both in Fort Worth, Texas. Quantitative and qualitative analyses supported the factorial validity and reliability of the MCI. The findings suggested that the use of science kits with textbook integration created a more positive learning environment in terms of student satisfaction and cohesiveness than did classrooms with either textbook only or science kits only.

To further validate the use of MCI for assessing elementary school climate, Sink and Spencer (2005) reported a study conducted with grade 4–6 students in Washington State. The study used a short form version of MCI, the MCI-SF, containing 25 items in four scales derived from the original 38-item MCI. Data were collected from a total of 2,835 students representing 67% of the K–6 elementary school in the state.

The results of quantitative and qualitative analyses supported the validity and reliability with the four-scale MCI. Higher Cohesion and Satisfaction scores were an indicative of positive and healthy classroom environments, while the mean scores Competitiveness and Friction scale indicated a lack of classroom collaboration.

An unpublished but useful study conducted by Bennett (2002) used the five scales of MCI (Satisfaction, Friction, Competitiveness, Difficulty and Cohesiveness) to assess the perceptions of the school social climate. Data were collected from 262 sixth-grade mathematics students. Correlation analysis for the five scales revealed little or no scale intercorrelations. Also, univariate analysis of variance revealed that students' achievement in mathematics was a function of students' socioeconomic status. The data also showed that there was a significant relationship between the climate factors of friction and difficulty and mathematics achievement.

Fraser and Fisher (1986) investigated an elementary school teacher's classroom environment in Sydney, Australia with both the actual and preferred versions of the MCI using data obtained from 26 sixth-grade students of lower ability attending a coeducational government school. At the end of the first phase of the study, the teacher received feedback and was provided with a variety of suggested intervention strategies that could facilitate change in the classroom environment. The second phase involved the re-administration of the MCI. Results showed statistically significant reductions in actual–preferred discrepancy for the competitiveness and cohesiveness scale, but little of no significant changes occurred for the other three scales of the MCI.

Fraser and O'Brien (1985) used the MCI in association with word knowledge and reading comprehension tests with 758 third-grade students from 32 classes in eight schools from Sydney, Australia. Simple correlations were statistically significant both for word knowledge and comprehension for the cohesiveness, difficulty, friction, and satisfaction scales. However, the competitiveness scale showed a nonsignificant relationship with achievement. The result of multiple regression analysis showed that students' perceptions of their classroom environment accounted for 77% of the variance in word knowledge and 72% of the variance in comprehension.

Majeed, Fraser and Aldridge (2002) validated a modified version of MCI in a study involving 1,565 secondary mathematics students from 81 classes in 15 government secondary schools in Brunei. The results replicated previous findings and revealed a satisfactory factor structure for a refined three-scale version of MCI assessing cohesiveness, difficulty and competition. The results further showed that each scale displayed satisfactory internal consistency reliability and discriminant validity and was able to differentiate between the perceptions of the students in various classes. The study also revealed differences between boys and girls in their classroom environment perceptions.

2.3.4 Science Laboratory Environment Inventory (SLEI)

Interactions among learners and teachers within the science laboratory classroom environment are unique and therefore require a specialized instrument (Fraser, Giddings & McRobbie, 1995). The development of the SLEI was initiated with an awareness of the importance of laboratory lessons in science education (Fraser, McRobbie & Giddings, 1993). The SLEI was originally developed in a 'class' form containing five scales, each with seven items in each scale (Student Cohesiveness, Open-Endness, Integration, Rule Clarity, and Material Environment). Fraser and Tobin (1991) found that problems were encountered when classroom environment instruments are used to differentiate between subgroups within a classroom. This problem is most evident when the class form is used to assess a student's perceptions of the class as a whole rather than his or her role within the classroom. Because of these complexities and difficulties in assessing individual perceptions using scales that address the whole class, Fraser, Giddings & McRobbie (1995) developed a 'personal' form of SLEI to assess a student's perceptions of his or her own role within the class.

The SLEI has effectively been used in a number of studies to establish associations between classroom environment perceptions and students' cognitive and affective outcomes in Australia (Fraser, Giddings & McRobbie, 1995) and Singapore (Quek et al., 2001; Wong & Fraser, 1996). Fraser et al. (1993) cross-nationally validated the instrument using 3,727 senior high school students in 198 science laboratory classes in six countries: Australia, United States, Canada, England, Israel and Nigeria. In another study, Fraser and McRobbie (1995) administered the actual and preferred versions of the Personal Form of the SLEI to 516 grade 11 chemistry students from 56 classes in Queensland, Australia. This study validated the SLEI and enabled a comparison to be made of these two forms of the instruments. The study also found that associations existed between classroom environment perceptions of students and their attitudes towards science laboratories. Fisher et al. (1997) replicated the results of previous studies of strong validity and reliability for the SLEI with a sample of 489 senior high school biology students in Australia.

The Personal form of SLEI was validated in conjunction with the conventional Class form that assesses a student's perceptions of the class as a whole. The instrument was cross-nationally field-tested and validated with 5,447 students in 269 senior high school and university classes in six countries, and cross-validated with 1,594 senior high school students in 92 classes in Australia. Fraser et al. (1995) observed that each SLEI scale exhibited satisfactory internal consistency reliability, discriminant validity, and factorial validity, and differentiated between the perceptions of students in different classes. Furthermore, the mean scores obtained on the Class form were consistently more favorable than the corresponding Personal form. Also, in terms of sex differences, females generally held more favorable perceptions than males, but larger differences were observed for the Personal form than the Class form. The study further revealed associations between attitudinal outcomes and laboratory environment dimensions.

Fraser and Lee (2009) investigated high school science laboratory classrooms in Korea. The study involved the use of SLEI administered with 439 high school science students in 13 classes to assess their perceptions of their science laboratory classroom environment. The sample comprised 145 students from the humanities stream, 195 students from the science-oriented stream and 99 students from the science-independent stream. The results replicated previous findings revealing that Korean high school students show relatively favorable perceptions of their laboratory lessons, with the lowest score occurring for the Open-Endedness scale. The findings also supported a priori five-factor structure of the Korean-language version of the SLEI, with all of the scales showing satisfactory internal consistency reliability. Interviews and observations regarding laboratory classes reflected the results obtained from quantitative analysis. Comparison of the three streams showed that students from the science-independent stream perceived their classroom environments more favorably than did students in the other two streams.

In Asia, the SLEI has been cross-validated and found useful in research involving both its original English form and translated versions. In Singapore, using the English version of the SLEI, Wong and Fraser (1996) confirmed a strong relationship between students' perceptions of their science laboratory classrooms and their attitudes for a sample of 1,592 students in grade 10 chemistry classes. Also, Quek et al. (2005a) validated the English version of SLEI in a study that involved 497 gifted and non-gifted chemistry students in Singapore.

Interestingly, Santiboon et al. (2012) adapted the preferred and the actual versions of the SLEI to form the Physics Laboratory Environment Inventory (PLEI) and then translated it into Thai language. The PLEI was used to investigate the effects of physics laboratory classroom learning environments in Udon Thani Rajabhat University classes and also to help to improve the performance of students in Foundation Laboratory Physics course. Data were collected from 577 students in 13 classes from 5 physics teachers. Results revealed that students tend to prefer more student cohesiveness, open-endness, integration, and rule clarity, and an enhanced material environment in their laboratories. Also, the data showed that all of the five scales were positively associated with students' attitudes to physics laboratory classes.

Lightburn and Fraser (2007) further validated the SLEI in an evaluation of the use of anthropometric activities in biology classrooms in terms of student outcomes (achievement and attitudes) and classroom environment. Data were obtained from 761 high-school biology students in Florida. Results supported the SLEI's factorial validity, internal consistency reliability and ability to differentiate between classrooms. Also the efficacy of using anthropometric activities was supported by the differences observed between pretest and posttest achievement data, as well as by a comparison of the anthropometry group and a control group in terms of attitudes and perceptions of classroom learning environment.

2.3.5 Constructivist Learning Environment Survey (CLES)

Over the years, there has been a paradigm shift in teaching and learning from teacher-centered to more student-centered classroom environments (Wanpen & Fisher, 2004). Collaborative and student-centered learning environments can lead to enhanced learning, attitudes and perceptions of the learning environment (Hurst, 1996; Kim, Fisher & Fraser, 1999; Padron, Waxman, Brown, & Powers, 2000; Taylor, Fraser, & Fisher, 1997). Collaborative techniques are fundamental for constructivist learning environments.

Inquiry-based learning is designed on the framework of constructivist epistemology, with learners applying prior knowledge to construct new knowledge by using a variety of learning resources (Sobat, 2003). Fraser (1998a) suggested that constructivism is a cognitive process, which involves interactions and collaborations between learners and their environments through shared knowledge. Bukova-Güzel and Alkan (2005) considered that learning in constructivist terms is both a process and the result of questioning, interpreting, and analyzing information. Learning often takes place within a set environment, where students are presented with the resources that create interactive simulations as well as enhance their ability to construct new knowledge.

Constructivist epistemology has greatly influenced learning in science and mathematics classrooms (Cannon, 1995). According to the constructivist view, meaningful learning is a cognitive process in which individuals make sense of the world in relation to the knowledge which they already have constructed, and this sense-making process involves active negotiation and consensus building. However, this cognitive process occurs as students demonstrate self-discovery, acquisition and application of new knowledge, and competence (Young, 2005).

Social constructivists suggest that active learning takes place when teachers are constantly engaging learners in conceptually-rich educative interactions (Taylor & Maor, 2000) and when learners are provided with the opportunity to construct new knowledge and discoveries through meaningful negotiations (Kim, Fisher & Fraser, 1999). Constructivism provides a framework for enhancing learners' understanding and ability to apply and interpret new knowledge. Therefore, based on the fact that classroom culture has a strong influence on learning outcomes and how students' perceive their classroom environments (Fraser, 2001), the increasing quest to investigate constructivist teaching strategies (Walker, 2004), and the extent to which classroom environments are consistent with constructivist epistemologies (Fraser, 1998a, 2002; Wanpen & Fisher, 2004), the Constructivist Learning Environment Survey (CLES) was developed (Taylor & Fraser, 1991). However, Taylor (1996) developed a revised version of CLES to incorporate a socio-cultural perspective. The new version of the CLES assesses students' perceptions of the fundamental elements inherent in constructivist learning environments.

The CLES was developed to assist teachers and researchers to measure students' perceptions of the constructivist classroom (Aldridge, Fraser, Taylor, & Chen, 2000). The original version of the CLES (Taylor & Fraser, 1991) focused primarily on a psychosocial view of constructivist reform geared toward assisting students to become co-constructors of knowledge (Taylor, Fraser &Fisher, 1997). Despite the successful validation of the original version of CLES across several nations, Taylor and Fraser (1991) reported that the theoretical foundation on which the original CLES was formed was somewhat limited. Taylor (1996) later developed a new version of the CLES in order to incorporate a critical constructivist component of the classroom environment. Aldridge et al. (2000) noted that this development takes into account the socio-cultural factors that affect learner's cognitive constructive ability. The new version of CLES was designed to measure five key elements of a critical constructivist learning environment from students' perspectives.

There has been widespread use of the CLES in investigations of classroom environment (Nix, Fraser, & Ledbetter, 2005; Taylor, Fraser & Fisher 1997; Taylor, Fraser, & White, 1994; Wanpen & Fisher, 2004). The CLES was designed to enable teachers and researchers to monitor their constructivist classroom environments (Johnson & McClure, 2000; Nix, Fraser & Ledbetter, 2005) and to assist teachers to reflect on their pedagogical skills in order to modify and reinforce their teaching practices. The CLES has 36 items with five frequency response alternatives that measure Personal Relevance, Uncertainty, Critical Voices, Shared Control, and Student Control (Fraser, 2002; Taylor, Fraser & Fisher, 1997). The instrument also has two versions: a preferred form which measures perceptions in terms of goal and value orientations preferred by the student; and the actual form which measures students' perceptions of actual experience within the environment (Fraser, 1998b; Taylor, Fraser & Fisher 1997).

Exploratory research conducted by Cannon (1995) further validated the CLES for use in an introductory college science courses for biology, chemistry and physics. Two different versions of CLES were administered, namely, a preferred form and a perceived form. Statistical analyses revealed that the preferred and perceived versions of the CLES had acceptable internal consistency reliability. The researcher therefore suggested that college science teachers should assess their learners' preferred and actual learning environments.

Aldridge, Fraser and Sebela (2004) cross-validated and used a modified version of the CLES in South Africa with 1,864 intermediate and senior-level students in 43 classrooms of 29 teachers from six schools. The research supported previous studies and validated the efficacy of the CLES. The authors contended that the CLES can provide effective feedback to teachers to help them in modifying their instructional delivery.

Taylor, Dawson and Fraser (1995) reported a study that involved action research and a large-scale survey in examining the suitability of the CLES for science classrooms environments and the effectiveness of the inclusion of a critical theory perspective in assessing the sociocultural framework of the learners. In order to address one of the critical questions about the plausibility of CLES for science classroom learning environments, the authors analyzed the results for four of the five scales of CLES to provide insights into a classroom environment under epistemological transformation; this study led to the modification and refinement of the student-perceived version to form a new version of the CLES.

The validity and reliability of CLES were established in a study conducted by Kim, Fisher and Fraser (1999) that involved the administration of translated versions of both the preferred and actual forms of the CLES to 1083 high school science students of 24 teachers in 12 schools. Four of the schools were located in the metropolitan area, another four schools were located in a small-sized city, and four schools were in the rural areas of Korea. The numbers of boys and girls were almost the same in each local area and at each grade level. Kim et al. (1999) reported that their results replicated previous findings in that there were positive relationships between grade 10 and 11 students' outcomes and their learning environment perceptions. Grade 10 students perceived more positively their learning environment of General Science, involves inquiry learning, than grade 11 students who studied an academic-centered science curriculum. It was also observed that there were statistically significant relationships between classroom environment and student attitudes. The authors concluded that the study was particularly valuable because it identified differences in perceptions and outcomes across grade levels, thus providing needed information for improving instruction in classrooms.

Eskandari and Ebrahimi (2013) evolved a Persian version of CLES to assess university chemistry classroom environments in Iran. The Persian version was contextually translated and back translated into Persian language from the original CLES. All items of the new instrument are scored on a five-point frequency scale with Almost Never representing the most negative perceptions and Almost Always representing the most positive perceptions. Data were collected from 415 Iranian university students in 17 chemistry classes (204 male students and 211 female students). Each scale of the instrument for both the actual and preferred forms of the Persian version had sound internal consistency reliability. Overall, students preferred a more positive classroom environment than the actual classroom for all the five dimensions of the instrument.

Mvududu (2003) further established strong validity and reliability for the CLES in a cross-cultural comparison of the perceptions and learning outcomes of Zimbabwean students. In particular, Mvududu (2003) concluded that Zimbabwean students perceived their classrooms as being relatively constructivist.

In similar research, Wanpen and Fisher (2004) investigated the impact of constructivist learning environments in computer classrooms in Thailand in order to guide the design of methods of implementing constructivism in such classrooms. A Thai-language version of CLES was administered to 710 students, first in the preferred form and later in the actual form. Puacharearn and Fisher (2004) validated a Thai version of the CLES with 606 science students in upper-secondary school in a study of cooperative learning that was integrated with constructivist teaching. The Thai version of CLES showed satisfactory reliability and validity and the research suggested that classrooms incorporating cooperative learning and a constructivist learning style promoted positive changes in both learning outcomes and students' attitudes. Students were found to be quite active and more in control of their learning, and teachers were able to improve their classroom learning environments using feedback from the CLES.

Johnson and McClure (2000) used a revised version of the CLES consisting of 30 items in five scales to assess graduate students' and teachers' perceptions of their graduate classroom environments. The CLES was administered to a wide range of people including elementary and secondary school science and mathematics teachers and elementary and secondary school students. The CLES was further modified by Johnson and McClure (2000) by keeping the same five dimensions but reducing the number of individual items to four per dimension for a total of 20 items. This newer form of the CLES, referred to as the CLES (20), was validated using exploratory factor analysis similar to that conducted by Taylor, Fraser, and White (1994). The new version of the CLES was found to be consistently reliable for all the scales of the instrument. The study provided valuable information about the interactions and relationships between graduate teachers and their students

Nix, Fraser and Ledbetter (2005) validated a new Comparative Student version of Constructivist Learning Environment Survey (CLES-CS) with 1,079 students from 59 classes in North Texas. Strong factorial validity and reliability were reported. Teachers who attended a professional development program perceived their science classrooms more favorably in terms of Relevance and Uncertainty compared with the teachers who did not attend. The instrument containing 30 items in five scales was used to evaluate the impact of the innovative teacher development in terms of students' perceptions of their science learning environments (Nix, Fraser, & Ledbetter, 2005).

Bukova-Guzel and Alkan (2005) examined the effectiveness of the adoption of a new curriculum which was designed on the framework of the Constructivist Learning Approach (CLA). The CLES was used to collect quantitative data from 600 grade 4 and 5 students (253 male and 347) whose ages ranged between 10 and 12 years and who attended the Pilot Elementary Schools of Izmir, Turkey.The original version of the CLES was translated into Turkish to determine students' experiences in the constructivist learning environment. The study was conducted primarily to assess the effectiveness of the curriculum, as well as to identify problems that could confront the application of the curriculum. All five scales had satisfactory internal consistency reliability. While students had positive opinions about the application of the CLA, the result from interviews with teachers showed that they had problems with the adoption of the new curriculum.

Aldridge et al. (2000) validated English and Chinese versions of the CLES in a study of high school science classrooms in Australia and Taiwan. The study combined qualitative methods with quantitative analysis of the five-scale, 30-item instrument. The CLES and an attitude scale were administered to a sample of 1081 grade 8 and 9 general science students from 50 classes in 25 schools in Western Australia and 1879 grade 7–9 students from 50 classes in 25 schools in Taiwan. Findings based on qualitative data from observations and interviews supported the cross-cultural viability of the CLES. Though observations supported some of the quantitative data, some qualitative information was not consistent with mean scores obtained from the CLES. Findings from the quantitative analysis of CLES supported the reliability and validity of both the English and Mandarin versions. The *a priori* factor structure was replicated with nearly all items loading on their own factor and no other factor. Internal consistency (Cronbach alpha coefficient) for two units of analysis, ability to differentiate between classrooms, and discriminant validity, all were found to be acceptable. Positive and statistically significant associations were found between students' attitudes and the five scales of the CLES for both Taiwan and Australian data.

Peiro and Fraser (2009) modified and translated the CLES into the Spanish language and administered the English and Spanish versions of the questionnaire to 739 grade K–3 science students in Miami, USA. The results confirmed the validity of both versions when used with lower-elementary students. The study also showed positive associations between students' attitudes and their learning environments, and that an intervention conducted with these students for three months led to some important changes in classroom environment.

2.3.6 What Is Happening In this Class? (WIHIC)

The What Is Happening In this Class? (WIHIC) questionnaire brings parsimony to the field of learning environment by combining modified versions of the most salient scales from a wide range of existing questionnaires with additional scales that accommodate contemporary educational concerns such as equity and cooperation (Fraser, 1998a). The WIHIC is the most widely-utilized classroom environment instrument for assessing students' perceptions of their learning environment. The robust nature of the WIHIC questionnaire, in terms of reliability and validity, has been widely reported in studies in different subject areas, at different age levels and in nine different countries (Dorman, 2003). The WIHIC was born out of the search for a single instrument that integrates the best characteristics of past classroom environment instruments.

In 1996, Fraser, Fisher, and McRobbie developed the original form of WIHIC. The original 90-item nine-scale version was refined by both statistical analysis of data from 355 junior high school students from Australia and extensive interviews obtained from students to form a seven scale, 56-item questionnaire (Aldridge, Fraser & Huang, 1999). The seven scales are Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, and Equity. The WIHIC has separate Personal and Class forms to measure the perceptions of students at the personal and class levels, and Actual and Preferred forms to measure the actual environment of the classroom and the environment preferred by the students. The 56-item WIHIC was later expanded to 80 items and field-tested using data obtained from 1,081 junior high school students from Australia and 1,879 junior high school students from Taiwan. This led to the development of the final form of the WIHIC by Aldridge, Fraser and Huang (1999). Strong factorial validity and internal consistency reliability have been reported by Aldridge and Fraser (2000) using the data obtained from Australia and Taiwan. The use of WIHIC by numerous researchers has revealed significant positive associations between students' perceptions of their classroom learning environment and their learning outcomes for most scales (Chionh & Fraser, 2008; Fraser, 2012; Riah & Fraser, 1998). Students respond using a five-point frequency scale: Almost Never, Seldom, Sometimes, Often and Almost Always.

Evidence from numerous studies involving the use of WIHIC have shown that classroom environment dimensions are useful criteria for evaluating the effectiveness of teaching and learning (Adolphe, Fraser & Aldridge, 2003; Aldridge & Fraser, 2000; Allen & Fraser, 2007; Chionh & Fraser, 2009; Kim, Fisher &Fraser, 2000; Khoo & Fraser, 1997; Koul & Fisher, 2003; Martin-Dunlop & Fraser, 2008; Ogbuehi & Fraser, 2007; Wolf & Fraser, 2008). Ogbuehi and Fraser (2007) evaluated the effectiveness of using innovative strategies for enhancing classroom environments and students' attitudes and conceptual development in four inner-city schools in Los Angeles County, California. Using data collected from 661 students in 22 classrooms, scales from WIHIC, CLES and Test Of Mathematics-Related Attitude (TOMRA) were validated. Statistical analysis showed that pretest and posttest scores were statistically significantly different, suggesting that innovative teaching strategies were effective.

Khine and Fisher (2001) investigated associations between students' perceptions of science classrooms learning environment, their attitudinal outcomes, and their cultural backgrounds in a study of the impact of teachers' cultural background in Brunei using the WIHIC and two scales of the Test of Science Related Attitudes (TOSRA) among 1,188 high school students from 54 science classes in Brunei. Significant associations emerged between most of the scales and teachers' cultural background. The results further supported the validity and reliability of the WIHIC. The authors observed that teachers from different cultural backgrounds created different classroom environments and therefore suggested that the WIHIC can effectively be used to guide improvements in the underlining conditions prevalent in the classroom.

In Jammu, India, Koul and Fisher (2003) pioneered a study that further confirmed the validity and reliability of the WIHIC for a sample of 1,021 science students from 32 classes in 7 private schools from India. The results of statistical and qualitative analyses showed that Indian classroom environments closely matched those reported for Western countries. It was observed that significant positive associations existed between the WIHIC and attitude scales, especially for Involvement, Task Orientation and Equity. Regarding gender differences, the authors observed that girls had more positive perceptions of their science classrooms than boys. From the analysis of the interviews, the authors concluded that education in India is focused predominantly on the development of the academic ability of the students.

Rawnsley and Fisher (1998) further validated the WIHIC and investigated associations between mathematics classroom learning environments and students' attitudes towards mathematics in Australia. The result supported previous findings in that students showed more positive attitudes towards mathematics in classes with positive learning environments, especially those where teachers were supportive and non-discriminatory.

The WIHIC has been successfully validated in combination with other classroom assessment instruments in internet-based classroom environments (Zandvliet & Straker, 2001). The authors investigated the physical and psychosocial environments in computerized school settings using the internet in classrooms. Data on psychosocial aspects of the environment were obtained by administering the WIHIC to 1,404 high school students who were making routine use of these computerized classrooms. Also, the physical settings were assessed using the Computerized Classroom Environment Inventory (CCEI) to collect data from 43 settings in 24 school locations in British Columbia, Canada and Western Australia. Potential deficiencies that were observed in the physical environment of these locations included problems with individual workspaces, lighting and air quality. The quality of the computer equipment selected and the available spatial environment were rated highly, whereas Visual and Workspace Environments in these settings were rated as being low. Zandvliet and Straker further observed some interesting associations between physical factors and the psychosocial learning environment scales. Students' Satisfaction was related to psychosocial factors such as Autonomy, Task Orientation, Cooperation, and Collaboration. Zandvliet and Straker (2001) concluded that the provision of adequate working environment transcends cosmetic demands and also helps to provide adequate physical learning environments that promotes psychosocial harmony.

Dorman, Fisher and Waldrip (2006) linked students' perceptions of learning environments with academic efficacy and attitudes to science in Australian secondary schools. Five of the WIHIC's scales were administered in association with other instruments to 449 students in secondary schools in Queensland. Results replicated previous findings concerning the validity of WIHIC. Confirmatory factor analysis showed sound model fit and satisfactory internal consistency. Multiple regression analysis showed that Student Cohesiveness, Teacher Support, Task Orientation, and Equity were significant independent predictors of academic efficacy and attitudes to science. Dorman et al. (2006) concluded that teachers who provide support to students, demonstrate equity in the classroom, ensure that students complete learning activities and engender student cohesion in science classrooms, are more likely to enhance their students' academic efficacy at science and attitudes to science.

The distinction between the actual and preferred versions of WIHIC was used by Chionh and Fraser (2009) in their study of attitudes, classroom environment and self-esteem in mathematics and geography classrooms in Singapore. This comprehensive study involved the use of the WIHIC among 2,310 Singaporean Grade 10 students in 75 geography and mathematics classes in 38 schools. The seven-scale factor structure was strongly supported and the alpha reliability of each scale was high. Investigation of associations between classroom environment and several student outcomes revealed that 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. Differences between the classroom environments of geography and mathematics classes were small relative to the large differences between students' actual and preferred classroom environments. Students with more positive attitudes and perceptions of their classroom environment tended to score better in examinations.

The WIHIC has been cross-validated in many subject areas and in numerous countries (Aldridge et al. 1999; Dorman, 2003). A comprehensive validation of

WIHIC was conducted by Dorman (2003) using a cross-national sample of 3,980 high school students collected from Australia, the United Kingdom and Canada. Confirmatory factor analysis supported the *a priori* factor structure of the seven-scale instrument. Also fit statistics indicated a good fit of the model to the data. The use of multi-sample analyses within structural equation modelling substantiated invariant factor structures for three grouping variables: country, grade level, and student gender. This study supported the wide international applicability of the WIHIC as a valid measure of classroom psychosocial environment. Similarly, Dorman (2008) used both the actual and preferred forms of WIHIC with a sample of 978 secondary school students from Australia. Separate confirmatory analyses performed for both the actual and preferred forms supported the seven-scale *a priori* factor. This study provided evidence of the sound psychometric properties of the WIHIC.

A recent study in China by Yang (2013) focused on the perceptions of junior secondary school students' mathematics classroom learning environments by administering WIHIC to a sample of 2,324 junior secondary school students from 72 classrooms. Factor analysis, descriptive statistics, two-way ANOVA, and cluster analysis revealed that Chinese junior secondary students generally did not perceive their mathematics classroom environments very favorably. Based on an analysis of gender differences in students' perceptions, boys were found to perceive their mathematics classes as more inquiry-oriented and perceive themselves as relatively more mathematically involved than girls, while girls perceived more cooperation.

Riah and Fraser (1998) cross-validated the English version of the WIHIC with 644 Grade 10 Chemistry students in 35 classes from 23 government secondary schools high schools in Brunei. When simple and multiple correlation analyses were performed, there was a significant association between perceptions of the learning environment and attitudinal outcomes. In particular, Student Cohesiveness, Teacher Support, Involvement and Task Orientation were positively associated with students' attitudes.

In Turkey, Telli et al. (2006) assessed high school students' perceptions of their classroom environment in biology using the WIHIC and students' attitudes toward biology using the Test of Science Related Attitudes (TOSRA). The researchers also investigated differences in students' attitudes toward biology by gender, grade level, and parental education. Data were obtained from 1,983 ninth and tenth grade students from 57 biology classes at schools in two major Turkish cities. The instruments were translated into the Turkish language by two bilingual teachers and pilot tested with 399 students. Correlation and regression analyses revealed that students' perceptions of their learning environment in biology were significantly associated with their attitudes. The study also indicated that students had moderately favorable attitudes and perceptions of their learning environment in biology, with higher ratings for Inquiry and Enjoyment than for Career Interest, Student Cohesiveness, Task Orientation, and Equity. In addition, there were significant differences based on gender and grade level. Also working in Turkey with a Turkish translation of WIHIC, den Brok et al. (2010) validated the WIHIC and established a learning environment profile using a sample of 1,474 high school biology students in 52 classes. The classroom environment profiles were: self-directed learning; task-oriented cooperative learning; mainstream, task-oriented individualized; low-effective learning; and high-effective learning.

Allen and Fraser (2007) investigated inquiry-based classrooms and used the WIHIC to assess the perceptions of parents and students of the classroom environment. The study involved the use of a six-scale modified WIHIC administered to 520 students (aged 9–11 years in grades 4 and 5) selected from 22 classrooms in three schools in large cities of Southern Florida. The result replicated previous findings using the WIHIC and showed satisfactory reliability and discriminant validity for both students and parents. The study also showed that students and parents preferred a more favorable learning environment than the one that they actually perceived. However, while students preferred more investigation in the classroom, parents preferred more teacher support.

Cakiroglu et al. (2007) further confirmed the validity of WIHIC in association with other classroom environment instruments. They examined grade 8 Turkish students' perceptions of their science learning environment using the WIHIC, teachers' interpersonal behavior using the QTI, and students' attitudes using TOSRA. The findings indicated a positive relationship between students' perceptions of their science teachers' interpersonal behaviors and perceptions of the learning environment and their affective outcomes. The result also revealed that Turkish students perceived their classes as highly task oriented and cooperative, moderately cohesive, teacher supportive, and equitable. Analysis of gender variations revealed that, for all dimensions of the WIHIC, girls viewed their learning environment in a more positive way than did boys.

In a cross-national study conducted in Taiwan and Australia (Aldridge et al., 1999, 2000), the WIHIC and the CLES were validated using samples obtained from 50 junior high school science classes in Taiwan (1879 students) and Australia (1081 students). The instruments were translated into Chinese language and back-translated into English language. Aldridge et al. (1999) also obtained qualitative data from interviews with teachers and students as well as data collected from classroom observations to complement the quantitative information. Data analysis supported the reliability and factorial validity of the questionnaires. The study also showed that the use of qualitative data provided valuable insights into the perceptions of students in each of the countries, helped to explain some of the differences in the means between countries, and highlighted the need for caution when interpreting differences between the questionnaire results from two countries with cultural differences (Aldridge et al., 1999, 2000).

2.3.7 Assessing Teacher Interpersonal Behavior Using Questionnaire on Teacher Interaction (QTI)

The nature of teacher–student interpersonal behavior has been shown to be a factor associated with student achievement and attitudinal responses to science learning, coupled with other classroom variables such as gender, socioeconomic and cultural background (Rickards, Newby, & Fisher 2001). Quek, Wong and Fraser (2005a) asserted that, while extensive research has been undertaken into associations between the learning environment and student attitudes, less attention has been paid to the influence of teacher–student interactions. Wubbels, Creton and Holvast (1988) investigated teacher behavior in classrooms from a systems perspective theory (Watzlawick, Beavin & Jackson, 1967) that assumes that the behaviors of participants influence each other mutually. It implies that the behavior of the teacher is influenced by his or her students' behavior and that students' behavior, in turn, is influenced by the teacher's behavior.

To conceptualize the nature of the relationships between a teacher and his/her students, Wubbels et al. (1985) adopted a model developed by Leary (1957). In this model, behavior is defined with two independent dimensions, the Dominance–Submission axis and the Hostility–Affection axis. Wubbels and his colleagues observed a deficiency in this field of classroom environment research and, thus, began mapping the interactions between students and teachers using a theoretical model of Proximity (Cooperation, C and Opposition, O) and Influence (Dominance, D and Submission, S). Figure 2.1 shows the model of teacher interpersonal behavior developed by Wubbels et al. (1985). This circumplex model for interpersonal behavior has eight sectors (Fraser &Walberg, 2005) grouped into two dimensions labelled as Influence (Dominance–Submission) and Proximity (Opposition–Cooperation).The eight sectors which ascribe facets of teacher behavior are labelled as follows: Leadership DC, Helpful/Friendly CD, Understanding CS, Students' Freedom SC, Uncertain SO, Dissatisfied OS, Admonishing OD, and Strict DO. In figure 2.1, sections of the model are labelled according to their position in the coordinate system. For instance, the two sectors of leadership and helpful/friendly are both characterized by Dominance and Cooperation, while the Dominance/Submission (DS) dimension is primarily comprised of behaviors in the sectors closest to the DS axis–Strict, Leadership, Uncertainty and Student Responsibility/Freedom. In the DC sector, the Dominance aspect prevails over the Cooperation aspect. The sectors that predominantly make up the Co-operation/Opposition (CO) dimension are Helpful/Friendly, Understanding, Dissatisfied and Admonishing. Therefore, a teacher displaying DC behavior might be seen by students as enthusiastic, a good leader and the like.

The modification of Leary's model by Wubbels et al. (1985) paved the way for the development of the Questionnaire on Teacher Interaction (QTI). Wubbels and Levy (1993) believed that, when the QTI is administered to both teachers and their students, it provides information about their perceptions of the interpersonal behavior. This includes perceptions of the behavior of the teacher towards the students and perceptions of the behavior of students towards the other students. It also compares the nature and quality of relationships that exist between the teacher and his or her students within the classroom. The Original QTI questionnaire developed by Wubbels et al. (1985) consisted of 77 items, on a five-point frequency scale ranging from Never/Not at All to Always/Very Often.

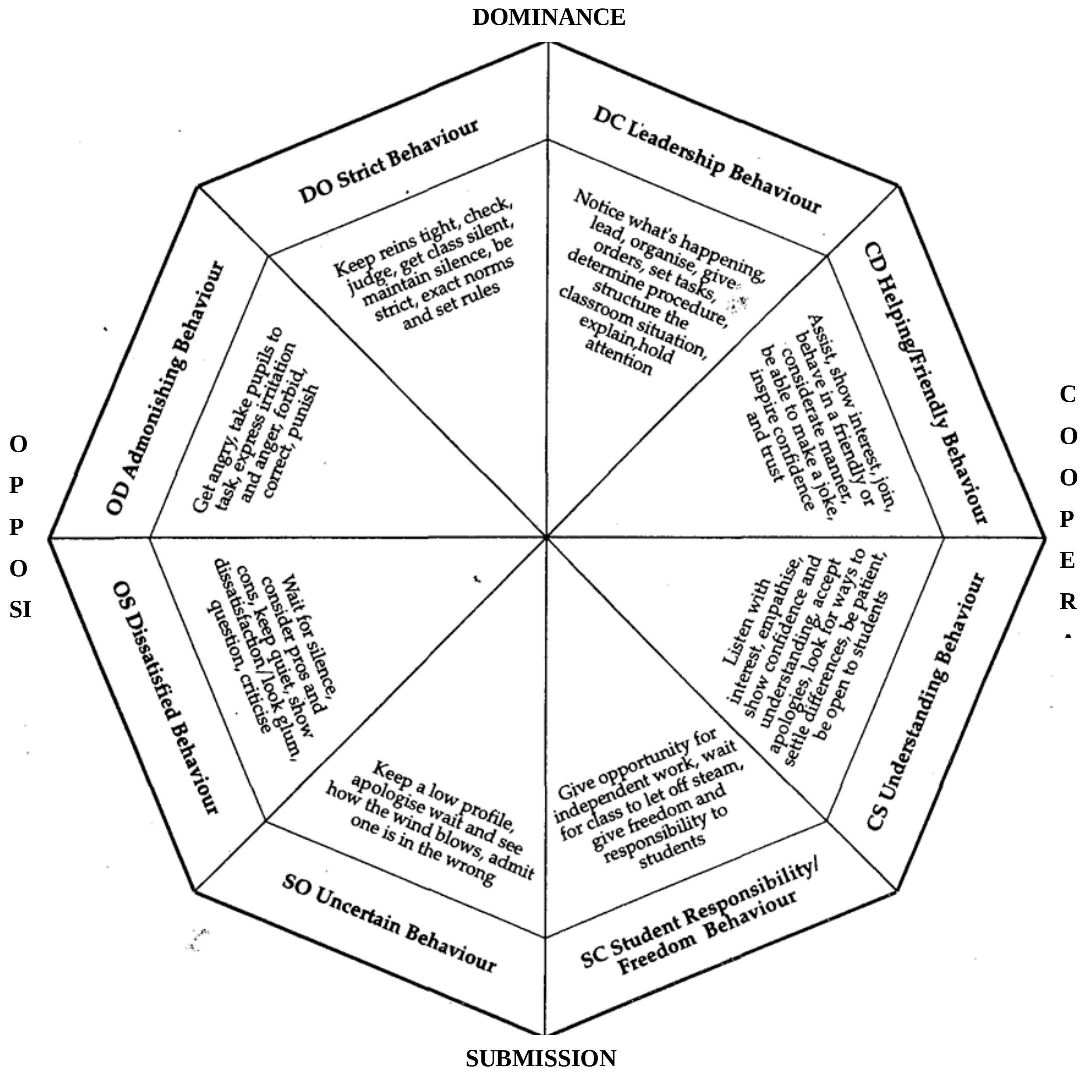

Figure 2.1 Model for Interpersonal Teacher Behavior (Wubbels et al., 1985)

Within the domain of learning environments, a considerable amount of research on teacher–students interpersonal behavior has been carried out in different countries to show that teachers’ interpersonal behavior is a fundamental determinant of student attitudinal outcomes in Australia (Fisher, Fraser, & Wubbels, 1993; Fisher, Henderson, & Fraser, 1995; Henderson, Fisher, & Fraser, 2000), the USA (Akey, 2006; den Brok, Levy, Rodriguez, & Wubbels, 2002; Levy et al., 2003; Wubbels & Levy, 1991, 1993), Asia (Baek & Choi, 2002; Goh & Fraser, 1998; Khine & Fisher, 2003). The QTI has become the focus of many classroom environment studies and has been successfully translated and validated in at least 15 languages around the world, including English, French, German, Hebrew, Russian, Slovenian, Swedish, Norwegian, Finnish, Spanish, Mandarin Chinese, Singaporean Chinese, Indonesian, Malay and Korean (Fraser & Walberg, 2005). This instrument, like other learning environment instruments has followed the strong tradition in learning environments research of assessing the perceptions of the participants in the classroom (Fraser & Walberg, 2005). The QTI has been used in successfully in Australia (Fisher et al., 2005), Brunei (den Brok, Fisher & Scott, 2005b), India (den Brok, Fisher & Koul, 2005), The Netherlands (Brekelmans et al., 1990), Singapore (Goh & Fraser, 1998) and the USA (Wubbels & Levy, 1991, 1993; Rickards, Newby, & Fisher 2001).

In the past two decades, quite a number of studies with the QTI have been reported for various academic subjects and curricula such as mathematics (Goh & Fraser, 1996, 1998), biology (Fisher, Henderson & Fraser, 1995), science (Khine & Fisher, 2004) and chemistry (Fisher, Rickards, Goh & Wong, 1997a; Quek, Wong & Fraser, 2005a, 2005b) at the elementary, secondary and pre-university levels. Quek, Wong and Fraser (2005a) observed from previous studies that classes with directive teachers (i.e. those who provide a well-structured task-orientated learning environment) and tolerant/authoritative teachers (i.e. those who provide a pleasant, well-structured environment and who have a good relationship with students) were associated with the greatest cognitive and affective gains for students. Students' affective outcomes are enhanced when there is a positive interaction between students and teachers within the classroom (Aldridge, Fraser & Huang, 1999; Fraser, 1998a).

Past learning environment research (Fraser, 1998a; Wubbels et al., 1991) has revealed that teachers typically perceive their classrooms more positively than do their students in the same classrooms. However, there exists another small group of teachers who perceive their classrooms less favorably than their students in terms of their relationships with students (Fraser & Walberg, 2005). Wubbels et al. (1991) observed that the magnitude of the difference between teachers' and students' QTI scores is directly related to the quality of teacher–student relationships. In a pioneering study conducted in Western Australia and Tasmania, Wubbels (1993) analyzed QTI data from 46 teachers to show that teachers perceived their classrooms more favorably than the students did. Wubbels observed that students perceived that their best teachers are those with more leadership, friendly, admonishing and understanding behaviors, with less uncertain and dissatisfied behaviors.

Similarly, Rickards, Newby and Fisher (2001) reported using the QTI to compare students' perceptions of teacher–student interactions with their teachers' perceptions. The questionnaire was administered to 1,659 students in 80 lower-secondary school classes in Tasmania and Western Australia, with approximately equal number of grades 8, 9 and 10 students. The students were given the student version of the QTI, while teachers completed the teacher-self and teacher-ideal versions. Analyses showed significant differences indicating that the teacher's perceptions of interactions affect the class's perceptions, and that the class's perceptions also affects the teacher's perceptions but to a lesser degree.

Quek, Wong and Fraser (2005b) further validated the QTI in conjunction with other instruments in an investigation involving 497 high school gifted and non-gifted chemistry students from three independent schools in Singapore. The 48-item QTI was used to assess the perceptions of students' and teachers' interpersonal behavior in chemistry laboratory classrooms. Also, data were collected using the 35-item Chemistry Laboratory Environment Inventory (CLEI) and the 30-item Questionnaire on Chemistry-Related Attitudes (QOCRA). Statistical analysis supported the validity and reliability of the CLEI and QTI for this sample. Stream (gifted versus non-gifted) and gender differences were found in actual and preferred chemistry laboratory classroom environments and teacher–student interactions.Multiple regression analysis performed separately for each of the three attitude scales for the whole set of eight QTI scales revealed significant associations between students' attitudes towards chemistry and both the laboratory classroom environment and the interpersonal behavior of chemistry teachers. Statistical analysis also confirmed the reliability and validity of the QTI for use with secondary school students.

Den Brok et al. (2005) investigated the relationship between teacher–student interpersonal behavior and students' attitudes toward science in Kashmir, India using multilevel analysis. Data were collected from 1,021 high school science students located in 31 classes using the QTI. An Australian version of the QTI consisting of

48 items was administered to students and teachers. The findings replicated previous studies in that both Influence and Proximity had a positive effect on students' attitudes. Also, interpersonal variables were found to be strongly associated with attitudes when student covariates and other learning environment variables were taken into account. When multilevel analyses of variance were conducted for students' attitude scores, both teacher Influence and Proximity were positively associated with students' attitudes.

A review of validity and reliability studies involving the QTI over a period of 17 years shows that the reliability of each of the eight scales of QTI is satisfactory and consistent across classes (Rickards, den Brok & Fisher, 2005). A study reported by Goh and Fraser (1996) also confirmed the validity of the QTI in Singapore with 1,512 students in fifth grade from 39 mathematics classrooms in elementary schools. Each QTI scale exhibited satisfactory internal consistency reliability and predictive validity for two levels of analysis (the student and the class mean) and differentiated between the perceptions of students in different classes. The data also revealed that female students consistently rated teachers' interpersonal behavior more favorably than did males.

Patrick and Ryan (2003) suggested that students tend to demonstrate positive attitudes towards learning and their classroom environments when they perceive that their interaction with the teacher is supportive, promotes respect and is motivating. Despite differences that exist among students in their perceptions of their social environments, some degree of conformity also exists among students from the same classroom for all the dimensions (Patrick & Ryan, 2003). Although several studies have been conducted into student–teacher interpersonal relationships, more recently, the pendulum of research has swung towards gender differences among students and their effects on their relationships and interactions with teachers within their classroom environment (Kim, Fisher, & Fraser, 2000).

Scott and Fisher (2004) selected the elementary version of the QTI and translated it into Standard Malay. In order to assess the perceptions of the students and teachers, 3,104 students in 136 classrooms in Brunei were involved. Statistical analyses revealed that data from this Malay version of the QTI exhibited satisfactory validity and reliability of the QTI. The study also revealed positive associations between students' perceptions of their teachers' interpersonal behaviors and academic achievement. Students' perceptions of cooperative behaviors were positively correlated, while submissive behaviors were negatively correlated, with cognitive achievement. When compared with data obtained from Singapore and Australia, the results of the study in Brunei were found to be similar.

The perceptions of students and teachers of teacher–students interactions were assessed by Rickards and Fisher (1998) with the QTI for a sample of 3,515 students in 164 schools in Western Australia. Teachers' perceptions of the classroom were different from the way in which students perceived their classroom. Telli et al. (2007) reported another use of the QTI in Turkey to investigate the reliability and validity of a Turkish adaptation. A total of 674 students and teachers from 24 Grades 9–11 classes in two Turkish secondary schools were involved. The QTI was translated and back translated by selected teachers. The result of a pilot study led to further refinement of the instrument. Qualitative data involving interviews from teachers and students were also collected to establish the importance of teacher interpersonal behavior in the Turkish context. Qualitative and quantitative analyses supported the reliability and validity of the instrument. Turkish teachers were perceived by their students as very cooperative and moderately dominant.

Goh and Fraser (1998) validated the QTI in a study of interpersonal teacher behavior and classroom climate and their associations with affective and cognitive outcomes among primary mathematics students in Singapore using the QTI and the My Class Inventory. This pioneering study, which also examined gender differences in students' achievement, attitudes and perceptions of classroom learning environments, used data from 1,512 boys and girls students from government schools. Multilevel statistical analysis showed consistent associations between classroom environment and students' outcome. Regarding gender differences, multivariate analysis revealed that boys performed better in mathematics than girls, but girls generally viewed their classrooms more favorably than boys. Consistent with previous findings, Goh and Fraser (1998) observed that teacher–student relationships were linked to student outcomes both directly and indirectly through associations with other components of learning environment.

Wubbels and Brekelmans (1997) observed that there have been far too few intervention studies that provide feedback to teachers from the actual and ideal forms of the QTI to help improve teacher–student interpersonal relationships in their classrooms. Fraser and Walberg (2005) suggested that effective application of QTI would provide meaningful feedback to be used by teachers in guiding improvements in their classroom relationships with their students.

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

Outcomes-focused education has been applauded in many countries as an approach to school reform in which academic planning, instructional delivery and assessment have become the central focus for students' learning outcome (Aldridge & Fraser, 2008). In the past decades, significant research on the use of computers in classrooms has been conducted. However, few studies have investigated the psychosocial dimensions of computer classroom environments (Dorman, Aldridge & Fraser, 2006). Aldridge and Fraser (2008) incorporated all of the seven WIHIC's scale (Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Investigation, Cooperation and Equity), together with three other important scales that were salient in the context of the pilot schools, to form the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI). The instrument also incorporated the Differentiation scale from the Individualized Classroom Environment Questionnaire (ICEQ) to assess how teachers differentiate and modify lessons to accommodate students' learning abilities and interests. The Computer Usage assesses the extent to which students use computers as a communication tool and also to access information (Aldridge & Fraser, 2008). The TROFLEI contains 80 items (with eight items on each of 8 scales) with a five-point frequency response scales (Almost Never, Seldom, Sometimes, Often, and Almost Always). This instrument was developed using an intuitive-rational approach complemented by exploratory and confirmatory factor analyses.

The TROFLEI has been widely used and cross-validated in a number of studies across many countries, including Australia (Aldridge & Fraser, 2008; Aldridge, Dorman & Fraser, 2004; Dorman, Aldridge and Fraser, 2006), Turkey (Cakir, 2011), and the USA and Turkey (Welch et al., 2012). Aldridge et al. (2004) described the validation of actual and preferred forms of TROFLEI using multitrait–multimethod modelling. The instrument, consisting of 80 items in 10 dimensions, was used with 1,249 high school students from Western Australia and Tasmania. Construct validity was established using a multitrait–multimethod modelling with the 10 scales as traits. Overall, the results provided strong evidence for the sound psychometric properties of the TROFLEI.

Dorman et al. (2006) reported a study in Australia with the TROFLEI with a sample of 4,146 high school students, and used cluster analysis to develop a typology of classrooms by identifying five relatively homogenous groups of classroom environment. TROFLEI scales exhibited very good internal consistency reliability and sound factorial validity. The overall factor structure compared well with classroom environment instruments used in the past. Similarly, Aldridge and Fraser (2008) validated the TROFLEI in a study that monitored and evaluated the success of the new schools in promoting outcomes-focused education changes in students' perceptions of their classroom environments over 4 years. For the same sample of 4,146 grade 8–13 students, the data revealed interesting differences in the perceptions of males and females in terms of their classroom environment.

In a related study conducted in Turkey and the United States, Welch et al. (2012) further supported the cross-cultural validity and reliability of TROFLEI with a sample of 1,100 high-school students of whom 980 were from Turkey and 130 were from the USA. Scale reliability analyses and confirmatory factor analysis were performed separately for Turkish and US participants for both actual and preferred responses to each scale. All scales showed satisfactory internal consistency for both samples. Confirmatory factor analyses provided evidence of adequate model fit across both samples for both actual and preferred responses.

Koul, Fisher and Shaw (2011) validated the actual and preferred forms of the TROFLEI in New Zealand and investigated: differences between students' perceptions of actual and preferred learning environments; gender differences in students' perceptions; and associations between science classroom learning environments and students' attitudes and self-efficacy. The 80-item, 10-dimension version of both the actual and preferred forms of the TROFLEI was administered to 1,027 high-school students from 30 classes. The three affective outcomes in the study were attitudes to subject, attitudes to computers and academic efficacy. Statistical analysis established that the validity and reliability of the TROFLEI and the three affective outcome scales for use in New Zealand. Also, differences in actual and preferred scores confirmed that students participating in the study desired better learning environments. Female students generally perceived their technology-related learning environments more positively. Statistically significant associations were found between the scales of TROLFLEI and three affective outcomes.

2.4 Research on Classroom Environment

Research in classroom environment over the years has become increasingly diversified. For example, studies have shown that classroom environment changes across the transition from primary to high school (Ferguson & Fraser, 1998). Fraser (1986) noted that the quality of classroom environment is one of the fundamental determinants of teacher effectiveness and learning outcomes.

Six distinctive categories of classroom environment research have been extensively studied (Fraser, 1998a, 1998b, 2007). Figure 2.2 illustrates the six categories of classroom environment research that have involved the use of different classroom environment instruments. In this chapter, literature pertinent to three of these categories is reviewed: associations between classroom environment and students outcomes (Section 2.4.1); evaluation of educational innovations (Section 2.4.2); and sex differences in learning environment perceptions (Section 2.4.3).

2.4.1 Classroom Environment and Student Outcomes

Over the past decades, research has supported the view that student outcomes are related to classroom environments (Fraser, 2012; Meece, Anderman & Anderman, 2006; Yarrow, Millwater and Fraser, 1997). Meece et al. (2006) observed that considerable research evidence suggests that students show increased motivation and learning patterns when their school and classroom settings emphasize mastery, understanding, and improving skills and knowledge. Although school environments that are focused on competing for grades can increase the academic performance of some students, Ames (1992) examined the classroom learning environment's relationship to motivation. The structure of classroom learning environments is identified by the differences in achievement goals and the variations in the patterns of motivation. Ames discovered that task orientation, individual recognition, and authority dimensions of classrooms can influence students' achievement goals. Yarrow et al. (1997) and Ames (1992) agree that classroom structures and motivation can contribute to achievement. Ames (1992) believes that an important goal for teachers is to develop a learning environment that accommodates individual differences and allows all students to develop a sense of belonging. Bennett (2003) observed that, in classrooms characterized by public evaluation, students became more focused on their individual strengths and how they are distributed within the classroom groups. Bennett concluded that performance-oriented or competitively-oriented classroom environments encourage a focus on performance ability, but not on the use of strategies that required sustained effort over time.

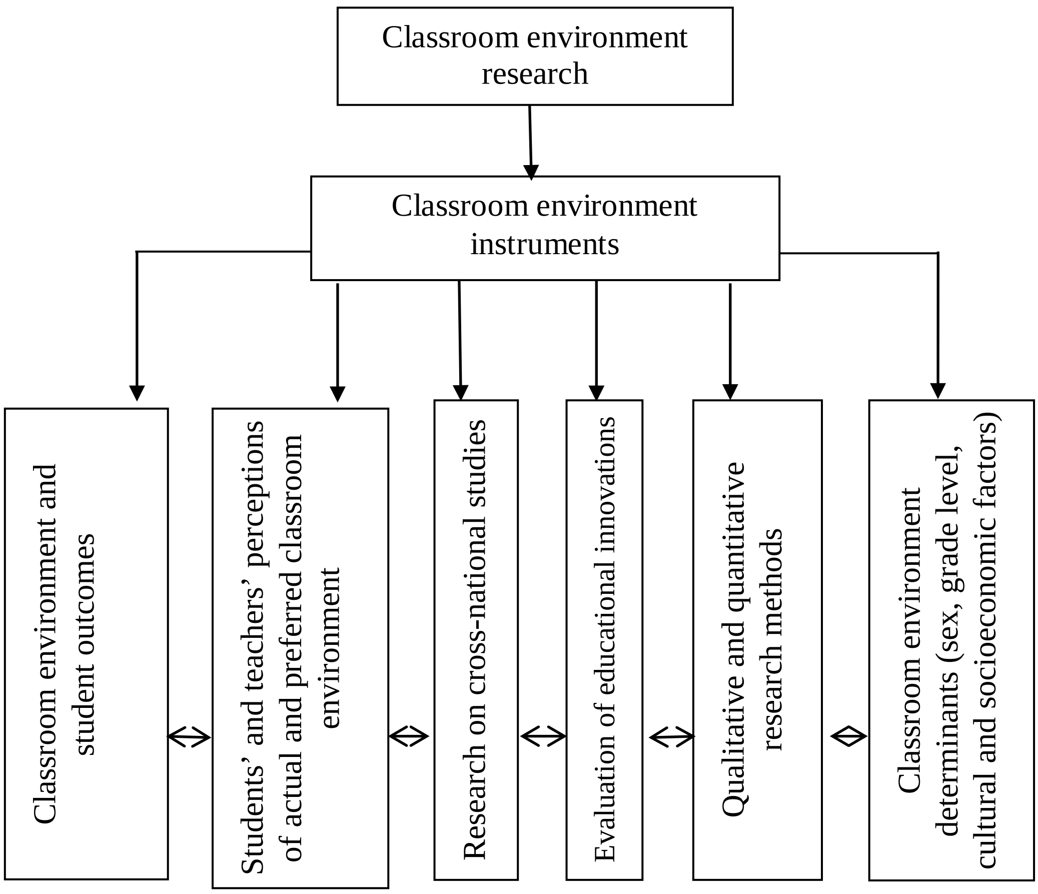

Figure 2.2 Six Categories of Classroom Environment Research

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 (Aldridge & Fraser 2008; Fraser, 2012). Researchers have found that student outcomes not only depend on curriculum, instruction, content, pedagogy, and assessment, but also on how students perceive their classroom environments (Fraser, 2001) and the quality of interactive relationship that exists between teachers and students throughout the learning process (Wanpen & Fisher, 2004). Baek and Choi (2002) recognized that classroom environment has been viewed as a critical milieu for students' academic achievement. In Asia, for instance, researchers have undertaken a wide variety of studies of associations between student outcomes and their perceptions of classroom learning environment. While some studies have involved English-language versions of questionnaires, other studies have involved learning environment questionnaires that have been translated into various Asian languages.

Baek and Choi (2002) investigated the relationship between students' perceptions of classroom environment and their academic achievement in Korea. The study involved the administration of the Korean version of Classroom Environment Scales (CES), called the Korean Classroom Environment Scales (KCES), to 1,012 students in grades 10 and 11 classrooms from the same school district. Analysis of the data revealed that there were statistically significant differences in classroom environment according to school and classroom organization. The results of multiple regression analysis showed that classroom environment was a good predictor of students' academic achievement.

In a study conducted in Singapore, Wong and Fraser (1996) established relationships between a variety of student outcomes and students' classroom environment perceptions assessed using the SLEI and an attitude questionnaire. The sample involved 1,592 Grade 10 chemistry students in 56 classes. Similarly, Goh and Fraser (1998) used both the MCI and the QTI with 1,512 primary mathematics students in 39 classes in Singapore to establish associations between the classroom environment and learning outcomes. In both of these studies, strong relationships were found between the classroom environment scales and students' outcomes.

In a study of relationships between students' perceptions of their classroom learning environments and students' outcomes at the beginning of the school year in Tasmania, Australia, six affective and three cognitive outcome measures were used in conjunction with the Individualized Classroom Environment Questionnaire (ICEQ) with 1000 8^{th} and 9^{th} grade students both from 33 suburban and rural schools (Fraser et al., 1983). The results of regression analysis using sets of student background characteristics and actual environment variables showed statistically significant associations between classroom environment factors and students' outcomes. The study also showed that, when students were satisfied with their classroom, they learned more content and they liked school and the subjects being taught more.

Dorman (2001) observed that, while many variables contribute to a student's sense of academic efficacy, quite importantly, the quality of classroom environment in specific subject areas is linked to the perceived academic efficacy in that subject area. In a study of the relationship between the psychosocial environment and academic efficacy, an instrument formed from a combination of What Is Happening In this Class? (WIHIC) and Constructivist Learning Environment Survey (CLES) was administered to 1,055 secondary mathematics students from Australia. Simple and multiple correlation analyses revealed statistically significant associations between classroom environment dimensions and academic efficacy.

Studies have shown that, beyond instruction, curriculum management, content, pedagogy, and the support system, learning outcomes also depend on cognitive and affective strategies (Fraser, 1998a). These strategies depend among other factors on students' attitudes and motivation in their classroom learning environment, the teacher's pedagogical content knowledge, and the support system within that learning environment. Marchant et al. (2001) investigated the relationship of both family and school contexts to students' academic achievement, as well as the mediating effects of students' motivations and academic self-competence between the family and school contexts and achievement. The investigation involved 230 grade 5 and 6 students. Student perceptions of parenting style and school atmosphere significantly predicted their school achievement; however, students' motivations and self-competence mediated the relations between students' contexts and their academic achievement.

Church et al. (2001) examined the relationship between undergraduates' perceptions of their classroom environment, their adoption of achievement goals for the course, and their graded performance and intrinsic motivation. The study evaluated three approaches: firstly, mastery goals that were linked to the presence of lecture engagement and the absence of evaluation focus and harsh evaluation; secondly, performance-approach goals that were linked to the presence of evaluation focus; and thirdly, performance-avoidance goals linked to the presence of evaluation focus and harsh evaluation. When the achievement goal variables were used as predictors of graded performance and intrinsic motivation, the perceived classroom environment influenced achievement goal adoption and, in turn, achievement goal adoption influenced graded performance and intrinsic motivation.

Dunn and Harris (1998) examined the relationship between students' perceptions of classroom climate and academic achievement. The study involved administration of a short form of My Class Inventory (MCI) to a group of 230 fourth grade students in the Southeastern part of the United States. The same group of students also took the state mandated achievement examination. The dependent variables included reading, mathematics, and language. Multiple regression analysis revealed that all of the environment scales showed statistically significant associations with students' achievement, except for cohesiveness which showed no significant relationship to student achievement.

Umo (2010) contended that the classroom environment plays a significant role in languages learning and investigated the relationship between students' perceptions of their classroom environment and their achievement in learning the Igbo language. The sample involved senior secondary school Ibo language learners from Enugu State, Nigeria. The study revealed that students perceived an average level of their classroom environment dimensions. Also, a statistically significant relationships existed between students' mean perceptions of learning environments and their academic achievement.

Some studies, however, did not show a significant positive relationship between classroom climate and academic achievement. When Culpepper (1993) analyzed the data collected from 698 teachers in 41 elementary schools, there was no significant relationship between climate and reading and mathematics achievement. In a similar study, Bennett (2002) investigated the relationship between classroom climate and students' achievement, while also considering the student characteristics of socioeconomic status and gender as predictor variables. Data involved the use of My Class Inventory's five scales among 262 sixth-grade mathematics students. Students' achievement data were obtained from the Stanford Achievement Total Mathematics scores. Multiple regression analyses revealed that little, if any, relationship for any of the five MCI scales and that these five classroom climate indicators combined together explained only 10.5% of the variance in mathematics achievement. The results also showed that mathematics achievement scores varied significantly with economic category membership but not gender.

2.4.2 Evaluation of Educational Innovations

Classroom environment instruments can be used as a valuable source of process criteria in the evaluation of educational innovations. The significance of assessing the efficacy of educational innovations in terms of the learning environment cannot be over-emphasized. In evaluating the outcomes of Australian Science Education Project (ASEP), Fraser (1979) observed that students who participated in the ASEP project perceived their classrooms as more satisfying. In California, quite a few studies have involved assessing the impact of educational innovations on classroom environments. Ogbuehi and Fraser (2007) evaluated the effectiveness of using innovative teaching strategies in Southern Californian inner-city middle schools using the WIHIC and CLES with 661 students.

Nix et al. (2005) conducted a study that involved classroom environment dimensions as criteria in evaluating innovative programs in education. The study used a comparative student version of the CLES with 1,079 students in 59 classes in evaluating the impact of an innovative teacher development program (based on the Integrated Science Learning Environment, ISLE, model) in school classrooms. Students whose science teachers had attended the ISLE program perceived higher levels of Personal Relevance and Uncertainty of Science in their classrooms compared with students whose teachers did not participate in the program. Also, significant differences were found to exist between the perceptions of students whose science teachers attended the ISLE program and the students whose science teacher attended alternative field trip programs.

Fraser and Raaflaub (2013) used a modified version of WIHIC in an investigation involving 1,173 students in 73 science and mathematics classrooms. The study investigated psychosocial factors in the learning environment when laptop computers were being used in the study of mathematics and science. This study combined qualitative and quantitative data-collection methods in describing and comparing mathematics and science classrooms in terms of students' perceptions of their learning environments and their attitudes.

In Australia, Dorman (2012) linked university students’ perceptions of their classroom environment and course experiences in an Australian university. The study used the College and University Classroom Environment Inventory (CUCEI) with 495 university students. Analyses revealed that improvements in the classroom environment were linked to more positive course experiences, which can be taken as indicators of institutional performance.

With the increasing pressure to incorporate information technology into schools and increasing interest in evaluating the effects of this technology on students, studies have focused on evaluating the impact of curricular and technological changes. In evaluating adult computer courses in Singapore, Khoo and Fraser (2008) investigated 250 students in 23 classes using the WIHIC. Students’ perceived their computer classes positively in terms of involvement, teacher support, task orientation and equity. Also in Singapore, Fraser and Teh (1994) evaluated a computer-assisted learning program in geography classrooms using Geography Classroom Environment Inventory (GCEI) in association with other instruments. Similar to previous research, their study revealed that students who used a computer-assisted program perceived their classrooms more positively than students who did not use the computer-assisted program.

In South Africa, Aldridge, Laugksch and Fraser (2006) used the School-Level Environment Questionnaire (SLEQ) to investigate the perceptions of teacher who were involved in outcomes-based education. Data obtained from 403 teachers revealed that teachers who were involved in outcomes-based education (OBE) perceived significantly more OBE Familiarity and Work Pressure.

Afari et al. (2012) used a classroom environment instrument to evaluate the effectiveness of integrating games into college-level mathematics classes. When the WIHIC was administered to 352 students in 33 classes in United Arab Emirates (UAE), students who were involved in mathematics games had more positive perceptions of their classrooms environment.

Several studies have examined constructivist learning environments. Oh and Yager (2004) investigated 136 grade 11 earth science students in Korean high schools using the CLES to determine the impact of implementing constructivist practices in science classrooms. Students' perceptions were positive, and these positive feelings toward science were associated with constructivist practices in science classrooms. Ya Ni (2013) compared students' performance in online and face-to-face classes in terms of interactions and efficacy in a public administration class in a Californian university. Students' performance as measured by grades was not controlled by the mode of instruction.

Singh et al. (2012) examined the constructivist teaching practices of five teacher leaders for Iowa Chautauqua professional development program using the CLES. The researchers further examined whether the implementation of a particular constructivist teaching model was successful. This model program was first developed to improve science education in elementary schools, as well as to prepare teachers for adopting new ideas consistent with constructivist processes.

Mink and Fraser (2005) investigated 120 fifth-grade students whose teachers participated in a Science and Mathematics Integrated with Literary Experiences Program (Project-SMILE) in terms of their perceptions and attitudes towards science reading, writing and mathematics. Similar to previous findings, students whose teachers participated in the SMILE program perceived their classroom environments more positively and with greater satisfaction than students whose teachers did not participate in the program.

2.4.3 Sex Differences in Classroom Environment Perceptions

There is a wide array of literature that describes the differences between boys and girls on a variety of variables including achievement, attitudes, locus of control, and self-concept (Aldridge, Fraser & Huang, 1999; Kim, Fisher & Fraser, 2000; Koul & Fisher, 2003).Anderman and Midgley (1997) recognized that teachers exert a strong influence over students on a daily basis and that the classroom environment, to a large extent, plays a significant role in the disparities observed in the attitudes of male and female students in middle and high school. Burke (1989) observed that significant differences in academic performances exist between boys and girls, but suggested that more research is needed to fully comprehend the reasons for these differences. Therefore, the apparent decline in motivation and the differences in achievement, perceptions, and attitudes, especially in science education, between genders from elementary to high school have become a central focus for some classroom environment researchers.

Rickards et al. (2003) conducted the first large study in the USA using the WIHIC with students in low-, medium-, or high-SES schools to investigate differences between male and female in attitudes and perceptions of science classroom learning environment. The study involved a sample of 1,720 students from eighth-grade science classes from 11 Californian schools. Statistical analysis showed that student gender was related to four scales: student cohesion, teacher support, task orientation and cooperation. For all of these scales, girls had higher ratings than boys, indicating that female had more favorable perceptions of the learning environment. Finally, teacher gender was related to student cohesion and investigation, with female teachers having higher scores for these scales.

Similar to previous findings, Gentry, Rizza and Gable (2002) observed that female students consistently perceived their classroom activities to be more enjoyable than did the male students. Gentry et al. (2002) obtained data from3,744 grades 3–8 students from the school districts that collaborated with the National Research Center for Gifted and Talented students. The data were collected from 163 classrooms in 24 schools, comprised of 16 elementary schools and 8 middle schools, in 7 states (Connecticut, Colorado, Michigan, Minnesota, New York, Ohio, and Virginia) from the eastern, northeast, mid-west and western United States. Significant effects existed for grade level and gender, with no interaction between the two variables. Middle-school students found that their classroom activities were less frequently interesting and enjoyable, with fewer opportunities for choice, than did elementary students. Student interest, choice, and enjoyment decreased as grade level increased, which is consistent with other studies of early adolescents' attitudes when they enter and progress through the middle school.

Kim, Fisher, and Fraser (2000) assessed students' and teachers' interpersonal behavior and their perceptions of the classroom environment using a Korean version of the WIHIC. The study also explored gender-related differences in students' perceptions of their learning environment and teacher behavior. Data were obtained from 543 eighth-grade students in 12 different secondary schools in metropolitan and rural areas of Korea. All of the scales of the Korean version of WIHIC showed satisfactory factorial validity and internal consistency reliability and there was a significant relationship between classroom environment and student outcomes. Also, there were statistically significant differences between the perceptions of boys and girls on all seven scales. In particular, boys perceived more Teacher Support, Involvement, Investigation, Task Orientation, and Equity than did girls.

In a study of gender differences in perceptions of classroom environment among 235 high-school students in Sipitang, Sabah, students were administered scales from WIHIC and CLES (Murugan & Rojo, 2013). Both descriptive and inferential statistical analyses showed that students had moderately positive perceptions of their mathematics classroom environments. However, mathematics achievement was low, with female students achieving better than males. There were no significant differences in perceptions of mathematics learning environments based on gender. The authors further observed that the correlation was weak between the mathematics classroom learning environment and mathematics achievement.

Hoang (2008) explained that, despite the emerging population of school-age students from minority groups in United States, these minority students remain underrepresented at every level. He considered that there is potential for a serious shortfall in the number of minorities entering the fields of science and mathematics. In a study conducted in Californian high schools, Hoang (2008) investigated how different factors, such as grade level, gender, and ethnicity, affect the attitudes and learning environment perceptions of high school mathematics students. To assess the perceptions and attitudes of the students, the WIHIC questionnaire and an attitude questionnaire based on the Test of Mathematics-Related Attitude (TOMRA) were administered to 600 Grades 9 and 10 mathematics students in 30 classes in one high school. Males consistently reported slightly more positive perceptions of classroom environment and attitudes than did females. Also, English-speaking Anglo students' consistently had higher scores than Hispanic students.

Wahyudi and Treagust (2004) explored gender differences in students' perceptions of their classroom learning environments using scales from WIHIC and TOSRA. The researchers investigated educational practices and learning outcomes in rural and urban lower-secondary school science classrooms of Kalimantan Selatan, Indonesia. 1,400 students responded to the WIHIC and TOSRA. Significant positive relationships were found between scales from modified versions of the WIHIC and TOSRA. Also, students preferred a more favorable classroom learning environment than the one that they actually experienced. As well, female students generally held slightly more positive perceptions of both actual and preferred learning environments, while students in rural schools perceived less positive learning environments than did their counterparts in urban areas.

Waxman and Huang (1998) reported the perceptions of 13,000 male and female students from urban elementary, middle and high schools. Female students generally had more favorable perceptions of their learning environment than did male students. Also, there were statistically significant differences by grade level. In general, middle-school students had less favorable perceptions of their classroom learning environment than did either elementary or high-school students. Huang (2003) further examined differences in students' perceptions of school and classroom environment according to variables such as subjects, academic background and gender. Previous research findings were replicated in that girls perceived their classroom learning environments more positively than did boys

2.5 Evaluation of Student Attitudes to Science

2.5.1 Issues in Assessing Attitudes

Over the years, the study of students' attitudes to science has become prevalent. Researchers have provided evidence that learning outcomes and students' attitudes towards their learning are correlated (Khine & Goh, 2001). Attitudes to science have been described in various ways by different authors. Allport (1937) defined attitude as a mental and neural state of readiness, organized through experience, exerting a direct and dynamic influence upon the individual's response to all objects and situations with which it is related. Gardner (1975) defined attitude towards science as a learned disposition to evaluate the ways, objects, people, actions, situations, or dispositions that are involved in learning science (p. 2). Gagne (1985) also defined attitude as a behavioral response that influences one's choice of personal actions that can manifest itself in personal social behavior. In his views, attitude, as a learning outcome, represents an internal state that influences the choices of personal actions made by an individual towards some class of things, persons, or events. Osborne, Simon, and Collins (2003) further defined attitude as "the feeling, beliefs and values held about an object that may be the enterprise of science, school science, and the impact of science on society or scientists themselves" (p. 1053).

Gardner (1975) maintained that the theoretical concept of' attitude towards science' has led to many attempts at its measurement and also at defining the construct of attitude. Gardner distinguished between attitudes towards science and scientific attitudes and explained that the latter signifies the longing and desire to know and understand a questioning approach to all statement, a search for data and their meaning and the demand for verification. Attitudes towards science represent the feelings, beliefs and values held about an object and can be the enterprise of science, school science, and the impact of science on society or scientists themselves. He further proposed that learned disposition presupposes how learners perceive science based on either level of motivation and interest or degree of boredom experienced in learning science. He considered that sex is probably the most significant variable that explains students' attitudes to science.

Hoang(2008) has shown that boys have a consistently more positive attitude to school science than girls. In support of this view, Osborne et al. (2009) agreed that students' interest and attitudes to science are significantly differentiated according to age and sex, as well as socioeconomic and cultural background. Osborne et al. (2003) identified two significant factors that hinder the assessment of attitudes in classrooms. Firstly, attitudes do not consist of a single unitary construct, but rather a large number of sub-constructs that contribute in varying proportions towards an individual's attitudes towards science. Secondly, attitudes are essentially a measure of the individual's expressed preferences and feelings towards science.

Klopfer (1971) categorized affective behaviors in science education into six conceptually-distinct categories:

- The manifestation of favorable attitudes towards science;
- The acceptance of scientific inquiry as a way of thought;
- The adoption of scientific attitudes;
- The enjoyment of science learning experiences;
- The development of interest in science and science-related activities; and
- The development of an interest in pursuing a career in science or science related work.

Of the subcategories in Klopfer's classification of attitudes, students' attitudes towards the learning of science was chosen as a major focus for my study. The development of TOSRA (Fraser, 1981) was based on the original classification by Klopfer (1971).

2.5.2 Assessing the Attitudes of Teachers and Students Using Test of Science Related Attitude (TOSRA)

Students' attitudes towards science have been widely investigated and documented across many countries using a purpose-designed attitude questionnaire developed by Fraser (1981) called the Test of Science Related Attitudes (TOSRA) (Chin & Wong, 2002; Eccles, 2007; Fisher & Fraser, 1982; Fraser, Aldridge & Adolphe, 2010; Fraser & Lee, 2009; Smith & Ezeife, 2010; Welch, 2010; Wong & Fraser, 1996;

Wood, 1998) Most of these researchers investigated the relationship between students' subject-related attitudes using the TOSRA and their perceptions of the learning environment assessed with one or more classroom assessment instruments. The central goal of science educators in maintaining effective classroom environments is to promote positive students' attitude to learning. Mager (1968) considered that positive students' attitudes tend to create sustained interest in science learning, and also that science learners can be influenced by peers. When Rawnsley and Fisher (1998) investigated associations between learning environments in mathematics classrooms using the WIHIC and students' attitudes towards that subject in Australia, the result revealed that students developed more positive attitudes towards mathematics in classes where the teacher was perceived to be highly supportive and equitable and to involve the students in the learning process.

TOSRA (Fraser, 1978), has been widely used by various researchers to assess students' attitudinal responses to their science learning experiences. Over the years, several studies have supported the efficacy of TOSRA for assessing students' attitudes towards their science classes. When Wood (1998) assessed high school classrooms in West Virginia using specialized educational software, significant relationships emerged between students' attitudes, their personal effort and their achievement. Chin and Wong (2002) further validated the TOSRA and used it to investigate associations between attitudes and classroom environment. A comparison of the results from multiple regression analysis and simple correlation analysis revealed that all the scales except competiveness showed a significant association between the nature of science classroom environment and student attitudes.

Smith and Ezeife (2010) used correlation and multiple regression analyses with data collected using a modified eight-scale version of the WIHIC and TOSRA among tenth-grade students in investigating perceptions of their classroom environment and attitudes towards science. The authors argued that teachers wanting to promote positive learning attitudes from students should monitor the transient features of the classroom environment. Wahyudi and Treagust (2004) further confirmed a significant relationship between students' attitudes and achievement and their perceptions of their classroom environment. Results from simple correlation and multiple regression analyses revealed that the use of modified Indonesian versions of

WIHIC and TOSRA replicated previous research findings concerning attitude–environment associations.

Sex and cultural differences in students' attitudes and perceptions of their classroom learning environment have been a focus for numerous researchers (Eccles, 2006; Kim, Fisher, & Fraser, 1999; Quek, Wong, & Fraser, 2002; Teng & Wong, 2001). Eccles (2006) provided further validation of a 48-item 8-scale version of TOSRA with 1,228 male and female science students in South Florida. Also, statistical analyses revealed sex differences in how each student perceived their teachers' interpersonal behavior, their attitudes towards science, and their science achievement.

Fraser and Lee (2009) concurrently used SLEI and TOSRA to investigate the perceptions and attitudes of students in Korean high schools. A total of 439 students in 13 classrooms were sampled from three different streams: humanities, science-oriented and science-independent streams. Statistically significant associations emerged between students' perceptions of their science laboratory classroom environment and almost all of the attitude scales assessed by TOSRA.

Several classroom environment studies have been reported in Singapore (Teh & Fraser, 1994; Wong & Fraser, 1995). In an exploratory study of associations between students' perceptions of their chemistry laboratory classroom environment and their attitudes towards chemistry, Wong and Fraser (1996) collected data from a random sample of 1,592 final year secondary school students in 56 chemistry classes from 28 coeducational government schools in Singapore. In assessing students' perceptions and attitudes of their chemistry classroom environment, the researchers used the Chemistry Laboratory Environment Inventory (CLEI), adapted from the original Science Laboratory Environment Inventory (SLEI), and the Questionnaire on Chemistry-Related Attitudes (QOCRA), developed from the original form of the Test of Science-Related Attitudes (TOSRA). Three analyses (simple, multiple and canonical correlation analyses) were performed to investigate environment–attitude associations. Overall significant associations were found between the nature of the chemistry laboratory classroom environment and students' attitudinal outcomes.

A cross-national validation of the TOSRA was recently reported by Fraser, Aldridge, and Adolphe (2010). The study also used the WIHIC to assess the science classroom environments in Australia and Indonesia. In order to cross-validate the WIHIC and TOSRA, as well as to investigate differences between countries and sexes in perceptions of classroom environments and attitudes, 1,161 students (594 students from 18 classes in Indonesia and 567 students from 18 classes in Australia) were involved. Factor analysis supported the validity of the modified WIHIC and TOSRA. Two-way multivariate analysis of variance showed some differences between countries and between sexes in students' perceptions of their classroom environments and attitudes. Simple correlation and multiple regression analyses revealed positive associations between the classroom environment and student attitudes to science in both countries.

The TOSRA is versatile and has been modified and used for other subjects besides science. For example, Walker (2006) developed and validated the Test of Geography Related Attitudes (TOGRA), an instrument modelled after the TOSRA, and used it with 388 grade 9 students from 17 geography classes in San Antonio. Ogbuehi and Fraser (2007) modified the TOSRA and renamed it the Test of Mathematics Related Attitudes (TOMRA) to suit mathematics classes. This study, involving 661 middle-school students in 22 classrooms in California, investigated the effectiveness of using innovative teaching strategies. In Florida, Adamski, Fraser and Peiro (2013) modeled the Test of Spanish-Related Attitudes on TOSRA and administered a Spanish-language version to 223 Hispanic grade 4–6 students.

Welch (2010) suggested that a major global challenge in the field of science education is retaining and educating students in science, mathematics, technology and engineering. In a study of high school students' attitudes toward science after participating in a robotics competition, Welch (2010) used TOSRA to measure students' attitudes toward science in seven categories: Social Implications of Science, Normality of Scientists, Attitude toward Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science, and Career Interest in Science. Students who participated in the robotics competition had more positive attitudes toward science and science-related areas for four of the seven categories examined: Social Implications of Science, Normality of Scientists, Attitude toward Scientific Inquiry, and Adoption of Scientific Attitudes. Students' participation and collaboration were contributing factors to the positive attitudes among students who participated in the science robotics competition.

Welch and Huffman (2011) reported another finding from research into secondary school students' attitudes towards science using the seven scales from TOSRA: Social Implications of Science, Normality of Scientists, Attitudes towards Scientific Inquiry, Adoption of Science Attitudes, Enjoyment of Science Lessons, Leisure Interests in Science, and Career Interests in science. TOSRA was administered to students who participated in the school robotics competition and to another group of students who did not participate in the competition. Statistical analysis revealed that students who participated in the robotics competition showed more positive attitudes towards science than the group that did not participate. Welch and her colleague concluded that programs and activities which engage students can significantly improve students' attitudes towards science learning.

Lowe (2004) assessed the attitudes of 312 science students in four rural secondary schools in New Zealand in an unpublished study that examined the effect of cooperative group work and assessment in science classrooms. Quantitative data were obtained using the 70-item TOSRA assessing 7 dimensions, while qualitative data were obtained from interviews. The study confirmed the reliability and validity of the TOSRA in New Zealand schools and showed that group work and group assessment enhanced students' attitudes to science, with both the teachers and students seeing real value in such activities, especially opportunities for formative group assessment. The TOSRA was also used to make comparisons of the science-related attitudes of several subgroups within the study population. Such comparisons included the effects of student sex, grade level and band, along with the role of the teacher and classroom environment, on student attitudes. The study revealed some statistically significant variations between the attitudes of males and females. Whereas females viewed scientists as significantly more normal than did male students, males reported significantly greater Enjoyment of Science Lessons.

2.6 Inquiry-Based Classroom Learning Environments

Over the years, there has been a shift from the traditional science laboratory approach to inquiry learning approach (Haury, 1993; Hinrichsen & Jarrett, 1999; Maor, 1991; Oliver, 2007; Wolf & Fraser, 2008; Wyatt, 1997). The assessment of inquiry-based classroom environments provides a means of monitoring, evaluating and improving science teaching and curriculum. Researchers and educators have recognized that one key factor that improves students' achievement and attitudes is to create learning environments that emphasize those characteristics that have been found to be linked empirically with improved outcomes (Hinrichsen & Jarrett, 1999). Wyatt (2005) agreed that providing students with opportunities to investigate through data collection enhances learning outcomes, but still remains one of the greatest challenges for science teachers and administrators.

Inquiry has become the heart of the National Science Education Standards. The U.S Department of Education and the National Science Foundation have developed mathematics and science curricula that incorporate an inquiry learning approach through problem-solving investigation, collaboration and exploration (Haury, 2003). The standards stipulate:

> *As used in the Standards, the central distinguishing characteristic between science and technology is a difference in goal: The goal of science is to understand the natural world, and the goal of technology is to make modifications in the world to meet human needs. Technology as design is included in the standards as parallel to science as inquiry.* (National Research Council, 1996, p. 24)

The National Science Standards suggested that science learning environments should reflect the intellectual vigor, attitudes and social virtues that characterize scientific inquiry (NRC, 1996). Such environments promote curriculum development, effective instruction, and assessment models as well as enabling teachers to build on learners' natural and human inquisitiveness. According to NRC (1996), inquiry is characterized:

> *...multifaceted activity that involves observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the result. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative [scientific] explanations.* (National Research Council, 2000, p. 13)

Hinrichsen and Jarrett (1999) reported that recent advances in cognitive research and developmental psychology, coupled with the present need to improve science education in an increasingly diverse society like the United States, have transformed our perceptions and attitudes towards the teaching of mathematics and science. Presently, educators and researchers have come to recognize that students learn best through connections with personal experience and integration of new ideas and information with their prior knowledge. The National Science Education Standards (NRC, 1996) attempt to redirect classroom science teaching to focus on scientifically-oriented questioning techniques, problem solving, learners' prior knowledge and skills, and active engagement in search for answers and explanations. Therefore, the standards identify the goal of science education as:

> *...that which educates students who are able to experience the richness and excitement of knowing about and experiencing the natural world; using appropriate scientific principles to making personal decisions, engage intellectually in public discourse and debate about matters of scientific and technological concern; and increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their career.* (NRC, 1996, p. 13)

Details of the goals of science as outlined by the National Science Education Standards are summarized below:

- Enhancing mastery of subject matter
- Developing scientific reasoning
- Understanding the complexity and ambiguity of empirical work
- Developing practical skills
- Understanding the nature of science
- Cultivating interest in science and interest in learning science and
- Developing teamwork abilities.

In 1992, the National Science Foundation (NSF, 1992) began the process of adopting inquiry-based practices in science classrooms. Again in 1996, the National Committee on Science Education Standards and Assessment published the new National Science Education Standards and suggested guidelines for the implementation of inquiry practices for science, mathematics, engineering, and technology. The blueprint suggested that students must develop the knowledge and skills needed for dealing with present-day scientific complexities (NSF, 1996). Educators and school administrators must also embrace the challenges that results from the dynamics of scientific and technological innovations. As a result, new educational reforms and science standards that focus on inquiry were formulated for improving students' learning and mastery of science. A positive learning environment is the fundamental key to effective inquiry-based science learning; therefore, it is foundational that teachers and school administrators strive to promote positive learning climates.

This section is devoted to expounding past research on inquiry practices and inquiry-based classroom environments. The historical development of inquiry-based learning, as well as a review of past literature pertinent to this study are described in this section. The changing perceptions of policy makers and school administrator towards academic achievement have resulted in many educational reforms and the enactment of new science standards. Therefore, this section explores the essential attributes to effective inquiry teaching and learning and also the relationship between inquiry practices, pedagogy, and constructivism. This section, which is divided into 10 subsections as described below, concludes with a discussion on the challenges and limitations of inquiry practices in science classrooms. These 10 subsections are:

Section 2.6.1 Historical Perspectives on Inquiry Learning
Section 2.6.2 Exploring an Inquiry-based Learning Approach

Section 2.6.3 Inquiry and Constructivism

Section 2.6.4 Research on Inquiry-Based Classroom Environment

Section 2.6.5 Teaching Science through Inquiry

Section 2.6.6 Essentials Features in Inquiry: A Broader Perspective

Section 2.6.7 Signs of Inquiry: Classroom Inquiry Indicators

Section 2.6.8 Integrating Pedagogy and Inquiry

Section 2.6.9 Why Practise Inquiry?

Section 2.6.10 Challenges and Limitations to Inquiry Learning.

2.6.1 Historical Perspectives on Inquiry Learning

The inclusion of inquiry in the K–12 science curriculum was suggested by John Dewey (1910), a former science teacher. By the 1950s and 1960s, the application of inquiry as an instructional approach became increasingly prevalent. As early as the turn of the century, Herbart's (1901) ideas about teaching included starting with students' interest in the natural world and in interactions with others. He proposed two ideas as a foundation for teaching: interest and conceptual understanding. The first principle involving interest is based on direct experiences with natural world as well as social interactions. Herbart identified the second principle of teaching foundations as the formation of concepts and asserted that each new idea must be related to extant ideas. That means that students learning experiences are built upon existing ones and, therefore, instructional models are developed as teachers observe students' interaction with others in the learning process and craft for themselves new learning experiences.

In 1916, Dewey suggested that scientific inquiry should follow the six steps of scientific process: sensing perplexing situations, developing conjectural anticipation by clarifying the problem, formulation and elaboration of a tentative hypothesis, testing the hypothesis, taking one stand upon the project hypothesis and revising the hypothesis with rigorous tests, and acting on the solution. According to Dewey, this model implies an instructional approach that is based on experience and, therefore, requires reflective thinking. In 1944, Dewey modified and broadened his earlier interpretation of the scientific method to include: presentation of the problem; formation of a hypothesis; collecting data during the experiment; and formulation of a conclusion. Project Synthesis, a scientific inquiry research compilation sponsored by the National science Foundation from 1955 to 1975, identified two fundamental dimensions of inquiry:

- Content for teachers and their students
- Strategy used by science teachers to help their students learn science (Welch, Klopfer, Aikenhead, & Robinson, 1981).

As early as the 1960s, research into inquiry learning heightened. Schwab (1966) suggested that the teaching of science inquiry should be a priority in science education, that teachers teach students both to conduct investigations in inquiry and to view science itself as a process of inquiry. He contended that inquiry should be perceived as a conceptual conjecture, implying that teachers should present science instruction through the act and process of inquiry. He emphasized the conception that science education should be approached through conceptualized inquiry.

In the field of mathematics, the adoption of inquiry-based learning began in the 1920s and was continued for half a century by R. L Moore of the University of Texas. Moore taught his students through a sequence of carefully-crafted problems and theorems using conjectures that enable students to construct their own proofs and justify their own reasoning to their peers. Since then, inquiry learning has metamorphosed into different forms and structures. In his review of the students' activities in science classrooms, Gagne (1963) observed that scientific inquiry is a set of interactive activities that engage students in problem solving. Haury (1993) posited that scientific inquiry has been characterized in a variety of ways and promoted from a variety of perspectives. Haury (1993) cited Alfred Novak's definition of inquiry as science that engages students in investigation and that inquiry is a set of human behaviors that is involved in the struggle for reasonable explanation of natural phenomena. Kyle (1980) identified the rapid rate of increasing dynamism that faced inquiry learning and claimed that inquiry is not and does not connote laboratory experimentation and investigation; rather, Kyle believes that learners' ability to demonstrate inquiry originates from an internalized ability to synthesize knowledge through demonstrations of basic skills and competencies.

2.6.2 Exploring an Inquiry-Based Learning Approach

Over the years, science teaching involving inquiry has been widely accepted and well supported by science educators (Haury, 1993) and is strongly endorsed by the National Science Education Standards (NSES; National Research Council, 1996). According to the NSES standards:

> *Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments.* (NRC, 2000, p. 105)

Trial-and-error practice has become the common technique for both children and adults in problem-solving, especially when faced with difficult situations. In an attempt to solve natural problems, we tend to analyze what is happening, predict what will happen next and reflect on our environment by observing, gathering, assembling, and synthesizing information. We identify resources and tools to measure and observe the problem so as to develop a model (NRC, 2000). Haury (1993) observed that there is no meaningful learning if there is no inquiring mind seeking for an answer, solution, explanation or decision. Inquiry in the classroom can range from students wondering how insects interact among themselves to the study of quantum and nuclear physics. But whatever its exact form, its role in education is becoming an increasing focus of attention. Today the world is being profoundly influenced by scientific discoveries. Learners need to make and evaluate decisions that require careful questioning, seeking of evidence, and critical reasoning. Therefore, inquiry presents the lines that connect the dots, bridging the known with the unknown. Lee (2004) observed that it is a difficult pathway for teachers who are accustomed to the traditional method of science instruction to transition to inquiry; however, for some of these teachers, inquiry-based learning requires a significant and exciting shift in perspective about the teaching and learning process. Students therefore need to be able to devise and carry out investigations that test their ideas, and they need to understand why such investigations are uniquely powerful. According to the National Science Education Standards (NRC, 1996), at the end of secondary education, science students should have acquired three kinds of scientific knowledge, skills and understandings:

- Students need to learn the principles and concepts of science.
- Students need to acquire the reasoning and procedural skills of scientists.
- Students need to understand the nature of science as a particular form of human endeavor (NRF, 1996).

Oliver (2007) likened inquiry-based learning to problem-based learning. Inquiry-based learning describes a learning approach in which learning is achieved through research and investigative activities in response to a given set of problems (Wyatt, 2005), and problem-based learning involves students in complex problem solving involving the application of knowledge (Bligh, 1995). Quite recently, greater emphasis has been placed on integrating technology into inquiry-based classrooms. Maor (1991) has reported studies on inquiry-based classrooms using computer facilities. As emphasized in the National Science Education Standards (National Research Council, 1996), students who use inquiry to learn science engage in many of the same activities and thinking processes used by scientists when seeking to expand human knowledge.

2.6.3 Inquiry and Constructivism

The general concepts, ideology and classroom applications of constructivism are well documented (Cannon, 1995; Fraser, 1998b; Johnson, 2000; Nix, Fraser & Ledbetter, 2005; Oliver, 2007; Taylor, Fraser & Fisher 1997). In early studies of inquiry-based learning, inquiry practices were built on constructivist epistemologies, an approach that originates from Socratic principles. Maor and Taylor (1995) and Maor and Fraser (1996) claimed that constructivism is a social behavior in which learners are engaged in the construction of new knowledge using prior experiences. In their review of past literatures, Maor and colleague identified the social environment in which learners interact socially and engage in meaningful knowledge construction. Harlen (2010) noted that constructivism transcends knowing students' ideas by helping them to understand scientific phenomena in a way that enables them to take an active part in constructing scientific knowledge. Students are therefore provided with the foundational opportunities that enable them to collect evidence to test their ideas, link ideas from one experience to new ones, consider alternative ideas, with scaffolding, and so on. In this way, teachers can help all of their students to understand science as a human endeavor, acquire the scientific knowledge and thinking skills important in everyday life and, if their students so choose, to pursue a scientific career.

The National Science Foundation (1996, p. 23) defined inquiry as "an approach to learning that involves a process of exploring the natural or material world, and that leads to asking questions, making discoveries, and rigorously testing those discoveries in the search for new understanding". Inquiry learning is based on the constructivist paradigm in which learners are involved in constructing their own knowledge through understanding of natural and scientific concepts. Constructivism has become a dominant approach in science classrooms across the globe (Mayer, 2004). Harlen (2010) explained that social constructivism involves sharing, discussing, defending ideas, dialogues and reflections. It also recognizes the impact of other ideas on the way learners make sense of things and the importance of language. Haury (2003) suggests that educators and researchers describe the constructivist model as active learning environment.

Over the past years, the constructivist approach has been reflected in science curricula across many countries. In these curricula, Kim, Fisher and Fraser (1999) noted that students are expected to learn and demonstrate mastery of basic scientific concepts through student-centered activities and negotiations. Recent research into cognitive learning and psychological development has transformed the way in which both teachers and learners perceive science education (Jarrett, 1997). As the US educational community gradually embraces the New Generation Science Standards (NGSS), greater emphasis has been placed on teaching science through inquiry. Kubicek (2005) observed that the pedagogical perspective that gives credence to inquiry strategies is that teachers who understand the structure and framework of constructivism tend to place more emphasis on questioning, prompting, brainstorming, and exploratory approaches. Ironically, however, Kubicek (2005) observed that most science teachers do not understand the process, goals and delivery techniques of inquiry. Many schools in the past decade have embraced the concept of constructivist epistemology as an influential learning approach in science education (Cannon, 1995). In inquiry-based classrooms, students are given opportunities to collect and analyze data (Wyatt, 2005) as a postmortem measure to providing answers to their inquisitive minds.

Inquiry has a meta-content (Wheeler, 2000) in that it is designed around other curriculum and content and practiced on a continuum throughout the learning process within the instructional process (Jarrett, 1997). Therefore, inquiry-based classrooms require a well-structured setup in which the teacher's role involves facilitating and guiding students through inductive and deductive reasoning towards solving scientific problems (NSF, 1999). It is a misconception to think that inquiry learning is all about laboratory investigations. However, as significant as laboratory experiments might be, inquiry transcends the act of doing and focuses on the act of searching. Although all inquiry experiences do not need to involve a "mop and apology to the custodian" (Jarrett, 1997, p. 5), they are resource-demanding and require investigative and technological tools. Experimentation in an inquiry-based classroom enhances the students' ability to understand the nature of science, as well as to assess experimental parameters and evaluate text (Wyatt, 2005).

2.6.4 Research on Inquiry-Based Classroom Environments

Quite a number of studies have focused on inquiry based-learning environments (Haury, 2003; Hinrichsen & Jarrett, 1999; Jarrett, 1997; Kubicek, 2005; Oliver, 2007; Wolf & Fraser 2008; Wyatt, 2005). Fraser (1994) asserts that classroom environment research has largely involved assessing and improving science education within the context of the traditional, dominant epistemology. Cannon (2005) posited that assessing constructivist classrooms environments involves the lenses of inquiry practices. Therefore, a classroom environment instrument is required to assess the extent to which a particular science classroom reflects constructivist epistemology (Fraser, 1994). Oliver (2007) reported that active learning through participatory investigation, questioning, problems solving, and critical-thinking strategies must be clearly evident in such a classroom for significant learning outcomes to be observed. Lee (2004) added that inquiry classrooms can promote students' ability to think critically, demonstrate a good habit of independent inquiry, and encourage students to take responsibility for their own learning and monitor their own intellectual growth and maturity. Oliver (2007) suggested that inquiry-based learning approaches could enhance students' independent learning skills. Glaser (1992) recommended that students should be able to describe a problem in detail before attempting a solution, determine what relevant information should enter the analysis of a problem, and decide which procedures can be used to generate descriptions and analyses of the problem.

Wolf and Fraser (2008) compared inquiry and non-inquiry laboratory teaching in terms of students' perceptions of the classroom learning environment, attitudes toward science, and achievement among middle-school physical science students. Scales from learning environment and attitude questionnaires were used to obtain data from 1,434 students in 71 classes. Analysis of the data provided strong validity and reliability for all scales of both instruments. For a subsample of 165 students in 8 classes, inquiry practices promoted more student cohesiveness than non-inquiry instruction, and inquiry-based laboratory activities were found to be differentially effective for male and female students.

Luft (2001) explored how an inquiry-based demonstration classroom for inservice teachers impacted the perceptions and practices of 14 secondary science teachers. The study obtained both in-class structured and semi-structured interviews from participants during their instructional practices. Analysis of the data showed that the inservice program had an impact on the participants, but that there were discrepancies among the six induction and eight experienced teacher participants: the induction teachers changed their beliefs more than their practices, whereas the experienced teachers demonstrated more change in their practices than their beliefs. Luft (2001) observed that the changing belief systems of the induction teachers could have resulted in the limited use of student-centered practices, whereas the established belief systems of experienced participants could have been conducive to student-centered practices.

In a longitudinal study conducted at Hampshire College Amherst, MA, Gibson and Chase (2002) examined the long-term impact of an inquiry-based Summer Science Exploration Program (SSEP), a two-week science camping program designed to stimulate greater interest in science and scientific careers among middle-school students. The sample consisted of 158 students selected from a pool of applicants who attended the program, and a stratified random-sampling procedure was used. Two questionnaires were used to collect quantitative data: the Science Opinion Survey (SOS) and the Career Decision–Making Revised Surveys (CDMRS). Analysis of pretest and posttest scores, as well as the interviews, revealed that the SSEP students showed more positive attitudes towards science and higher interest in science careers than students who applied to the program but were not selected.

Byers and Fitzgerald (2002) reported a study conducted by The Networking for Leadership, Inquiry, and Systemic Thinking (NLIST) initiative, sponsored by the Council of State Science Supervisors and NASA. The report suggested that systemic reform should be designed to facilitate inquiry learning in science classrooms by incorporating new knowledge about teaching and learning. Such targeted systemic factors include a standard conceptualization of science as inquiry, instructional materials, professional development, administrative support and leadership, facilities, community involvement, and technology infrastructure.

Roth and Roychoudhury's (1993) study conducted with grade 8 physical science students and 10^{th} and 11^{th} grade physics students showed their growth in knowledge, skills, and dispositions via extended open inquiry. Qualitative data indicated that students developed higher-order process skills through non-traditional laboratory experiences that enabled students to perform experiments of personal relevance in authentic context. They observed that student interpretation of results evolved from being simplistic to being able to identify complex relationships using multiple representations of experimental data. A significant observation by Roth and Roychoudhury was that students were able to define concepts, events, and actions when designing their experiments and communicating the results, and they became more adept at planning experiments when given the freedom to choose topics. Bransford et al. (1999) addressed the central question concerning what kind of learning experiences and learning environments promote science learning. He identified four categories of setting that must exist for effective inquiry learning to take place:

- The *learner-centered environment*, according to Bransford et al. (1999), reflects an environment where learners utilize their knowledge, skills, attitudes and beliefs in search of new knowledge. Prior knowledge becomes the rungs of the ladder on which learners would step in order to rise to the next level.

- The *knowledge-centered environment* describes the setting that helps learners to develop a well-organized body of knowledge that supports strategic planning and critical thinking.

- The *assessment-centered environment* is that setting that helps students to monitor and regulate their own learning in line with their thoughts and beliefs, thus providing learners with the opportunity to get feedback and revise their ideas.

- The *community-centered environment*, Bradford and his colleagues assert, helps learners to articulate their ideas, as well as to challenge the ideas of others in order to gain deeper understanding of the concept.

Oliver (2007) explored an inquiry-based approach conducted with first-year undergraduate students in an Australian university. The study specifically explored how the use of innovative technology supported reflective inquiry and long-term engagement that refined the classroom environment. Students were divided into groups of 25 and attended a weekly seminar under the supervision of an instructor. The adoption of the inquiry-based approach helped the students to develop sound strategies for understanding and for handling the problems and providing positive responses. On evaluation and reflection of the results, the study revealed that the inquiry-based learning approach provided a means to redirect students' learning towards the application of knowledge more than the traditional approach.

Chu, Tse, Low, and Chow (2011) showed that inquiry-based learning could greatly enhance students' academic performance through improvement in reading ability,and confirmed the effect of inquiry learning using group projects. The study involved students in fourth grade, teachers, and parents in a primary school in Hong Kong. Quantitative data concerning the perceptions of the students of inquiry-based learning were collected using questionnaires, while qualitative data were obtained from interviews. Also, a reading test called Progress in International Reading Literacy Study (PIRLS) was used to assess learning outcomes. Quantitative and qualitative data analyses showed positive effects for the reading abilities and attitudes among the participating students. Also, students' attitudes and self-perceived abilities appeared to influence the improvements in reading abilities.

In Australia, Taylor and Maor (2000) reported that a newly-articulated national curriculum had been under the lenses of researchers. The new curriculum required teachers of science, mathematics and technology to provide learning opportunities that vigorously engage students in conceptualizing ideas within a socially-interactive learning environment. Taylor and colleague reported a study of a new epistemological approach termed 'social constructivism' which defines the learner as an active conceptualizer. The primary focus of this study was to engage students in reflective and collaborative learning. In order to assess students' perception of their environment, the Constructivist On-Line Learning Environment Survey (COLLES), an electronic questionnaire that provides assessment of the students' perceptions of preferred online learning environments compared with the actual experiences. Based on the quantitative component of the study, students had very high expectations for relevance and interpretation. The students, however, preferred more cognitive support from direct interactions with teachers.

From the forgoing empirical studies, inquiry-based learning environments typically appear to have a positive impact on learning and provide rich opportunities for active learning and shared knowledge development. For positive students' achievement in science education, teachers should emphasize on the four inquiry classroom domains: learners, knowledge, assessment and community (NRC, 1996). Inquiry-based instruction should focus on providing multiple opportunities from diverse perspectives that support independent ideas (Ladewski, Krajcik, & Palincsar, 2007).The significance of classroom environment and its resultant impact on students' learning outcomes cannot be overemphasized. Research evidence has confirmed the reliability and validity of classroom learning environments instruments used to assess students' perceptions of and attitudes toward inquiry-based learning environments and their effect on students' learning outcomes. From a review of research, a common denominator underlies these investigations: student outcomes were improved in classrooms that were perceived to have positive, welcoming, and interactive environment.

2.6.5 Teaching Science through Inquiry

Scientific inquiry reflects how scientists come to understand the natural world, as well as being at the heart of how students learn (NTSA, 1992). For students to understand inquiry and its application in science learning, teachers need to be well-versed in inquiry and inquiry-based practices. Yet most teachers have not had opportunities to learn science through inquiry or to conduct scientific inquiries themselves. Nor do many teachers have the understanding and skills needed to implement inquiry thoughtfully and appropriately in their classrooms (NSF, 2000). The National Science Education Standards include guidelines, in the context of inquiry, for science teacher professional development. These standards are grouped into four categories:

- Standard A: Learning science through inquiry

- Standard B: Learning to teach science through inquiry:
- Standard C: Becoming lifelong ‘inquirers’
- Standard D: Building professional development programs for inquiry-based learning and teaching.

The National Science Standards recommended that, for teachers to teach their students science through inquiry, they need to understand the important content and ideas in science. They also need to know the evidence for the content that they teach and, most importantly, they need to learn the nature of scientific inquiry. The National Science Teachers Association (NSTA) recommends that all K–16 teachers embrace scientific inquiry and is committed to helping educators make it the centerpiece of the science classroom. For successful implementation of inquiry practices in classrooms, teachers must understand first and foremost, what inquiry is, and the structure of scientific discipline, as well as acquire needed skills for teaching inquiry.

The use of scientific inquiry in science classrooms helps students to develop deep understanding of real-world applications of science. NSF (1996) recognized that teachers must struggle with the tension between guiding students toward a set of predetermined goals and allowing students to set and meet their own goals. Teachers face a similar tension between taking the time to allow students to pursue an interest in greater depth and the need to move on to new areas to be studied. Rob Semper (Exploratorium, 1996) considers that the development of inquiry skills is beset with a tension between open-ended discovery and structured investigation. He noted that teachers help to reshape students’ views of science and therefore must step in when necessary during the course of students’ inquiry investigation. Although the teaching standards refer to inquiry, the standards made it clear that inquiry is not the only effective strategy for teaching science. Therefore, regarding the use of scientific inquiry as a teaching approach, NSTA recommends that science teachers:

- Plan an inquiry-based science program for their students by developing both short- and long-term goals that incorporate appropriate content knowledge.
- Implement approaches to teaching science that cause students to question and explore and to use those experiences to raise and answer questions about the

natural world. The learning cycle approach is one of many effective strategies for bringing explorations and questioning into the classroom.

- Guide and facilitate learning using inquiry by selecting teaching strategies that nurture and assess students' developing understandings and abilities.
- Design and manage learning environments that provide students with the time, space, and resources needed for learning science through inquiry.
- Receive adequate administrative support for the pursuit of science as inquiry in the classroom. Support can take the form of professional development on how to teach scientific inquiry, content, and the nature of science; the allocation of time to do scientific inquiry effectively; and the availability of necessary materials and equipment.
- Experience science as inquiry as a part of their teacher preparation program. Preparation should include learning how to develop questioning strategies, writing lesson plans that promote abilities and understanding of scientific inquiry, and analyzing instructional materials to determine whether they promote scientific inquiry. (National Science Teachers Association, 1992)

Table 2.2 describes the changed emphases envisioned by the National Science Education Standards (NRC, 1996) for promoting inquiry practices in science classrooms. The column on the left outlines the items requiring less emphasis, while the column on the right outlines the items requiring more emphasis.

2.6.6 Essentials Features in Inquiry: A Broader Perspective

Research has demonstrated that students who engage in inquiry learning often perform better on higher-thought assessments and equally well on traditional fact-oriented cognitive assessments (Costenson & Lawson, 1986).Inquiry demands a fundamental change in the relationship between teacher and student to one that is based on gained mutual respect among students and between teachers and students (Hinchinsen & Jarrett, 1999). As students collaboratively interact during the learning process, the interchange of ideas that develop requires constructive social skills. Mary DiSchino (Exploratorium, 1996) explains that the atmosphere of the classroom should be such that students feel safe to articulate ideas without fear of ridicule or judgment.

The National Science Standards provide detailed instructional guidelines for the implementation of science curriculum. The science standards are designed using the framework of inquiry (NSF, 1996, 2000). Wenning (2005) identified individual Climate Setting as one of the major components of education in traditional and inquiry classroom settings. Individual climate is likened to the significant role of the learner's metacognitive skills and its relationship to self-regulation. The National Science Education Standards identified metacognitive and self-regulatory practices as important tools for learning (NRC, 2000). Wenning explains that metacognitive and self-regulatory practices characterize student's ability to self-monitor levels of understanding.

Regarding the National Science Education Standards, the National Research Council (1996) has stated that inquiry into authentic questions generated from student experiences is the central strategy for teaching science. The national standards emphasize the investigative nature of science and the importance of students' active engagement in the construction of scientific ways of knowing and doing (NRC, 1996). Teaching through inquiry can take many forms, with most descriptions of inquiry emphasizing investigations. The NSES provides five essential features of teaching through inquiry (NRC, 1996):

1. Learners are engaged by scientifically oriented questions.
2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
3. Learners formulate explanations from evidence to address scientifically-oriented questions.
4. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
5. Learners communicate and justify their proposed explanations.

Table 2.2 Changing Emphases for Promoting Inquiry Learning in Science

Less Emphasis on	More Emphasis on
Knowing scientific facts and information	Understanding scientific concepts and developing abilities of inquiry
Studying subject matter disciplines (physical, life, earth sciences) for their own sake	Learning subject matter disciplines in the context of inquiry, technology, science in personal and social perspectives, and history and nature of science
Separating science knowledge and process	Integrating all aspects of science content
Covering many science topics	Studying a few fundamental science concepts
Implementing inquiry as a set of processes	Implementing inquiry as instructional strategies, abilities, and ideas to be learned
Activities that demonstrate and verify science content	Activities that investigate and analyze science questions
Investigations confined to one class period	Investigations over extended periods of time
Process skills out of context	Process skills in context
Emphasis on individual process skills such as observation or inference	Using multiple process skills-manipulation, cognitive, procedural
Getting an answer	Using evidence and strategies for developing or revising an explanation
Science as exploration and experiment	Science as argument and explanation
Providing answers to questions about science content	Communicating science explanations
Students analyzing and synthesizing data without defending a conclusion	Groups of students often analyzing and synthesizing data after defending conclusions
Doing few investigations in order to leave time to cover large amounts of content	Doing more investigations in order to develop understanding, ability, values of inquiry and knowledge of science content
Concluding inquiries with experimental results	Applying the results of experiments to scientific arguments and explanations
Management of materials and equipment	Management of ideas and information
Private communication of student ideas and conclusions to teacher	Public communication of student ideas and work to classmates

Adapted from National Science Education Standards (NRC, 1996)

Scientific inquiry can be summed up into two principal aims. First, as a result of students' learning experiences, they should develop an understanding of the defining qualities of science as a way of knowing and explaining the natural world. Secondly, students should develop, to a certain extent, some cognitive abilities and manipulative skills associated with scientific inquiry (Bybee, 2004). Though inquiry-based teaching strategies typically engage students in investigations, it is not the physical activity that defines inquiry, but rather inquiry is distinguished by its emphasis on the attitude of questioning, gathering data, reasoning from evidence, and communicating explanations that can be justified by available data. NSES identified two domains of inquiry:

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry.

2.6.6.1 Abilities Necessary to Undertake Scientific Inquiry

Inquiry learning requires students to present ideas consistent with scientific knowledge as they apply scientific reasoning and critical thinking skills to demonstrate knowledge of science. It is necessary for the learners to recognize and understand the changes and adjustments required for appropriate classroom conditions to occur. The NSES established guidelines for inquiry practices in science classrooms (NRC, 2000):

1. To identify questions and concepts that guide investigations. This includes formulating testable hypothesis with an appropriate design.
2. To design and conduct scientific investigations using major concepts, proper equipment, safety precautions, use technologies and use evidence and logic to construct argument for their proposed explanations.
3. Use appropriate technologies and mathematical models to improve investigations and communications.
4. Formulate and revise scientific explanations and models using logic and evidence using an explanation or a model.
5. Recognize and analyze alternative explanations and models (reviewing current scientific understanding and evidence).
6. Communicate and defend a scientific argument (with students refining their skills by presenting written and oral presentations).

Inquiry practices have certain identifiable traits that are observable in science classrooms. In a traditional teacher-centered classroom, the teacher remains the center of focus as he or she delivers the lesson to the students. Hinrichsen and Jarrett (1999) highlighted four essential and assessable traits of inquiry in science laboratory classrooms.

Making connections: In an inquiry classroom, students are challenged to make connections from their existing wealth of prior experiences and observation, in order to evaluate their ideas against those acceptable by science community. In the process, students are prompted to generate questions arising from intrigues and incongruities. The answers to their questions would depend on the factual observable data collected during investigation. As the learner reads, listens, speaks, or manipulates concrete objects, he or she makes important observations.

Designing experiments: As part of the inquiry process, students use the data obtained from observation to create a plan and procedure for investigation. Planning and designing are iterative in that they require reconsideration of previously-learned ideas, techniques, and decisions. They are also creative, inviting student scientists to use their experience and imagination to find an answer to their questions.

Investigating phenomena: Students carefully follow the established planning and procedural strategies, while observing any changes from the plan and identifying reasons for those changes. During investigation, data collection is actively involved and embedded in most interpretations of scientific inquiry process.

Constructing meaning from data and observations: Students' new knowledge is meaningfully constructed when they interact with science concepts by using language, management of their physical environment, the data collected and by critically reflecting on its meaning to gain further understanding. Students must notice and explain patterns, relationships and discrepancies observed as well as cite evidence of those patterns and identify limits, exceptions, or alternate interpretations of the data.

2.6.6.2 Understanding about Scientific Inquiry

For the second domain of inquiry, the NSES (NRC, 2000) stipulates that students should develop meaning about science and how scientists work. The six categories of understanding are listed below:

1. Develop conceptual principles and knowledge that guide scientific inquiries.
2. Investigations undertaken for a wide variety of reasons–for discovery, explanation of new phenomena, test results and predictions of theories.
3. Use technology to enhance data collection and analysis for greater accuracy and precision of the data.
4. Use mathematical tools and models to improve questions, data collection, constructing explanations, and communicating results.
5. Provide scientific explanations that are consistent with logical reasoning, follow rules of evidence that are open to question and modification, and are based upon historical and current science knowledge.

The National Science Teachers Association (NSTA) (1992) has adopted the National standards and has become a strong proponent for the national adoption, dissemination and implementation of the standards. The NTSA recommended the five phases and guidelines for the delivery of inquiry-based learning in science classrooms:

Phase 1 (Engage): Engagement with a scientific question, event, or phenomenon connected with their current knowledge.

Phase 2 (Explore): Exploration of ideas through hands-on experiences, formulating and testing hypotheses, problem-solving, and explaining observations.

Phase 3 (Explain): Analysis and interpretation of data, idea synthesis, model building, and clarification of concepts and explanations with scientific knowledge sources (including teachers).

Phase 4 (Extend): Extension of new understanding and abilities and application of learning to new situations (transfer).

Phase 5 (Evaluate): Review and assessment of what they have learned and how they have learned it (metacognition).

2.6.7 Signs of Inquiry: Classroom Inquiry Indicators

Looking into an inquiry classroom from the observer's perspectives, what would he or she expect to see? Harlen (2010) pointed out that not all learning in science involves inquiry and not all inquiry in science is scientific inquiry. The National Science Foundation (1999) identified salient indicators as benchmarks for inquiry science classrooms. Table 2.3 outlines some of the tangible indicators of inquiry practices observable in science classrooms. The left column of the table describes the key indicators readily practiced in science classrooms, while the right column describes the observable evidence demonstrated by the learner–facilitator relationship.

2.6.8 Integrating Pedagogy and Inquiry

The understanding that students are the primary drivers of their learning is the fundamental concept of pedagogy described as inquiry. This concept has evolved through changes to what is now widely known as Inquiry-Based Science Education (IBSE). Harlen (2010, p.48) defines pedagogy as not only the act of teaching but also the theories, values and justifications that underpin it and the skills and creativity needed to provide effective learning activities and to engage students in them.

Harlen further pointed out that how teachers teach science is directly influenced by their perceptions of how students learn science. Therefore she contended that inquiry learning is a constructivist pedagogy, which involves:

- helping students to understanding phenomena in a more scientific way, starting from the ideas that students bring from their previous experience
- enabling students to take an active part in creating their scientific understanding
- helping students to consider alternative ideas to their own through access to resources and discussion with others

- engaging students in discussion, sharing, dialogue, defending and reflecting on their idea.

Table 2.3 Classroom Indicators of Inquiry Practices

Indicators	Descriptions
1. Students View Themselves as Active Participants in the Process of Learning	a. They look forward to doing science. b. They demonstrate a desire to learn more. c. They seek to collaborate and work cooperatively. d. They show confidence and willingness to doing science; willingness to modify ideas, and take risks,
2. Students Choose to Learn and Readily Engage in the Exploration Process	a. They exhibit curiosity and ponder observations. b. They take time to persevere and think critically.
3. Students Plan and Carry Out Investigations	a. They design a fair test with minimal guardians. b. They plan ways to verify, extend, or discard ideas. c. They carry out investigations safely, observing, measuring, collecting and recording data
4. Students Propose Explanations and Solutions and Build a Store of Concepts	a. They express ideas in a variety of ways: journals, reporting drawing, graphing, charting, etc. b. They listen, speak, and write about science with parents, teachers, and peers. c. They use the language of the processes of science. d. They communicate their level of understanding
5. Students Raise Questions	a. They value and enjoy asking questions as an important part of science. b. They use questions that lead them to investigations.
6. Students Use Observations	a. They observe carefully and intelligently. b. They look for details, seek patterns, and detect sequences, similarities, and differences. c. They make connections to previously held ideas.
7. Students Critique Their Science Practices	a. They create and use quality indicators to assess their own work. b. They report their strengths and identify areas for improvement. c. They reflect with adults and their peers.

NSF (1999)

The NSF (1997) reported that inquiry teaching leads students to develop understanding of scientific ideas through direct experience and manipulations using materials, as well as by research and group discussions, argument, and debate among themselves. Hinrichsen and Jarrett (1999) pointed out that students often feel uncomfortable when walking into a science laboratory knowing that they would be expected to think critically throughout the duration of the class, especially when their prior knowledge of the lesson is vague. Hinrichsen and Jarrett suggested that the level of participation on the part of the learner depends on the structure and expectation of the classroom environment as well as the culture of learning in the classroom. Because the teacher creates the atmosphere for learning, when the student establishes a strong relationship with the teacher and thus becomes part of such a learning environment, students begin to understand that they have access to the domain of science.

2.6.9 Why Practise Inquiry?

Edelson, Gordin and Pea (1999) observed that inquiry practices in science classrooms can provide valuable opportunities for students to improve their knowledge and understanding in scientific practices. However, the implementation of inquiry learning in classrooms presents a number of significant challenges. In support of Edelson and his colleagues, Byer and Fitzgerald (2002) noted that inquiry-based learning is highly beneficial to science education. Such benefits include increased comprehension, development of thinking skills, first-hand observation and experience, collaboration, metacognition, and transfer. Haury (1993) added that inquiry-based learning in science education promotes scientific literacy, knowledge of science procedures, vocabulary, conceptual understanding, and positive attitudes toward science. In their support of the benefits of inquiry, Smart and Csapo (2007) explained that students learn best when they are directly involved in the practice of learning. In the process, the teacher must be vigilant about making necessary modifications for facilitating transition from one learning phase to another. In the act of facilitating inquiry-based learning, Smart and Csapo (2007) recognized that the teacher must consider the structure and organization of the classroom in order to maximize the opportunity for improved learning outcomes.

Edelson et al. (1999) considered that inquiry-based science learning provides the opportunity for learners to engage in scientific practices by themselves and therefore they identified four ways in which inquiry can contribute to the development of science content knowledge: firstly, inquiry activities can lead learners to confront the boundaries of their knowledge and recognize gaps in that knowledge. Secondly, successfully completing a scientific investigation requires some level of content knowledge. Therefore, in order to complete a science activity, learners need to acquire needed knowledge to complete the activity. Thirdly, by providing learners with the opportunity to pursue answers to questions, inquiry activities can enable learners to uncover new scientific principles and refine their preexisting understanding of their new knowledge construct. Fourthly, inquiry activities can give learners the opportunity to apply their scientific understanding in the pursuit of research questions (Edelson et al., 1999). In addition to these benefits, the National Science Education Standards stated that, when students are engaged in scientific activities based on inquiry, they would learn the following:

- understand the scientific concepts
- appreciate the 'how we know' what we know in science
- understand the nature of science
- develop the skills necessary to become independent inquirers about the natural world
- be readily willing and able to use the skills, abilities and attitudes associated with science. (NRC, 1996, p. 105)

2.6.10 Challenges and Limitations to Inquiry Learning

Although inquiry offers compelling opportunities for science learning, there are many challenges to the successful implementation of inquiry-based learning. In a study that investigated the use of scientific visualization technologies to support inquiry-based learning in geosciences, Edelson et al. (1999) identified five key challenges that face inquiry practices in science classroom environments:

1. *Motivation:* As exciting and supportive as inquiry practices might be, building sustainable motivation for students throughout the duration of the lesson can could be very demanding and challenging. Because of a high demand for intense critical thinking and deductive reasoning in inquiry activities, which most students always abhor, it becomes a tedious task not only for students but for the teachers to maintain the sustained period of motivation that is demanded by most traditional classroom environments.

2. *Accessibility of investigation techniques:* Oftentimes, inquiry laboratory practices can be complicated and required a high level analytical and

interpretative skills coupled with experience built on prior knowledge. Students must understand the expected outcomes of their investigations and be able to interpret their results.

3. *Background knowledge:* Because the entirety of the practice of inquiry requires prior content knowledge, it is challenging for students who lack prior skills and knowledge to develop and apply the scientific understanding needed to complete inquiry investigation.

4. *Management of extended activities:* Inquiry-based practices require completing complex open-ended activities that involve planning, coordination of activities and effective management of resources. Therefore it becomes challenging when students are unable to organize and manage an extended activities.

5. *The practical constraints of the learning context:* Recent demand for technological applications in science classrooms often becomes challenging for students who are not able to adjust to newer innovative technologies or fit into existing ones. Therefore, meeting the challenging needs from environmental constraints becomes a critical consideration in planning and designing inquiry based lessons

Costensen and Lawson (1986) conducted interviews with inservice traditional biology teachers who were reticent to use inquiry-based instruction in their own classrooms. He observed that teachers and administrators who are appreciative of the benefits of inquiry learning sometimes are disappointed and dismayed to learn that parents, administrators, and even teaching peers showed resistance to inquiry practices. He discovered that, for teachers, inquiry practices required more time for planning and preparation and specialized content and pedagogical skills in order to help students to reconstruct new knowledge. Constansen and Lawson further observed from teachers’ responses that inquiry learning takes more class time than is needed and often does not meet the goals of standardized achievement testing.

Bencze (2009) pointed out that one of the main problems encountered in an inquiry classroom is that many teachers experience interactional difficulty. This problem arises from the fact that teachers experience difficulty in channeling and maintaining the interest of students as they engage themselves in inquiry. Robertson (2007) added that implementing inquiry based-learning is cumbersome and requires careful and extensive planning and preparation for adequate content information to be imparted to the students. Oliveria (2009) observed that many science teachers are unprepared for the social demands associated with managing inquiry based classrooms. Skinner (1968) maintained that science education requires a large amount of data collection and computation using diverse resources such as books, charts, tables etc. A great deal of content knowledge is required for effective learning to take place.

Wenning (2005) observed that classroom climate affects the inquiry learning process. He described the whole-group climate setting or classroom climate as involving a satisfactory intellectual atmosphere in which inquiry instruction operates successfully. He believes that the roles of students and teachers differ within the classroom setting. Therefore, in this interactive role, teachers help students to understand the difference between traditional direct instruction and inquiry-oriented instruction. That means that the role of the teacher is to create a conducive climate for students to learn. Students, on the other hand must understand that learning is their responsibility and requires tools that they already have for constructing new knowledge. From the report of interviews conducted with teachers, Costenson and Lawson (1986) summarized the views and concerns teachers encountered during their inquiry lessons. Table 2.4 summarises these problems into 11 categories and provides a short description for each of the categories.

Table 2.4 Why Isn't Inquiry Used in School?

	Problems	Description
1.	Time and energy	It takes time to produce high quality inquiry and also sustainable energy needed for the high level of active learning
2.	Too slow	Inquiry takes more instructional time needed to cover the broad curriculum by the end of the school year
3.	Reading too difficult	Difficulty translating textbook knowledge into active inquiry
4.	Risk too high	Lack of support from school administration on inquiry practice due to a lack of sufficient content coverage
5.	Tracking	Because lower-performing students are the predominant group, effective inquiry practices may be impaired
6.	Student immaturity	Classroom management may create unstructured settings that would not support inquiry-oriented teaching.
7.	Teaching habits	Expository teaching habits are difficult to change after long periods of practice; teacher might not have skills needed for inquiry teaching.
8.	Sequential text	The textbook constitutes the curriculum; chapters cannot be skipped because too much important material is included in each.
9.	Discomfort	Teachers occasionally feel uncomfortable if not in control of the lesson, and are not certain of the outcomes inquiry teaching
10.	Too expensive	Lack of laboratory and technological resources needed to support the active engagement common in inquiry practice.
11.	High-stakes testing	Inquiry teaches those skills that are not addressed in such tests as the standardized tests.

Based on Costenson & Lawson (1986)

2.7 Chapter Summary

The overwhelming evidence from this literature review clearly shows that classroom environments have a significant impact on students' outcomes. Beyond curriculum and classroom instruction, the quality of classroom environments as perceived by the students and teachers is related to academic achievement and other student outcomes. Interestingly, classroom environment research has become very popular over the past four decades beyond a focus on the physical classroom environment to a focus on the psychosocial, cognitive, and emotional interactions of the students and teachers. Apparently, teachers' and students' perceptions have become an integral part of educational dynamics, coupled with computer technology and curricular changes.

This chapter provided an in-depth critical analysis of past literature on classroom environment and inquiry-based learning. It described the use of various instruments for assessing students' and teachers' perceptions of classroom psychosocial environment. Eight classroom environment instruments were reviewed in this chapter: Learning Environment Inventory (LEI), Classroom Environment Scale (CES), Questionnaire on Teacher Interactions (QTI), My Class Inventory (MCI), Constructivist Learning Environment Survey (CLES), What Is Happening In this Class? (WIHIC), Science Laboratory Environment Inventory (SLEI), and Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI). The review showed that these classroom environment instruments have consistently been shown to be valid and reliable in numerous countries. Particular attention was paid to reviewing literature devoted to the WIHIC and CLES because scales for my study were selected from these two questionnaires.

The review of classroom environment research in this chapter included studies of associations between classroom learning environments and students' cognitive and affective outcomes. These studies consistently confirmed that associations exist between students' outcomes and their perceptions of the psychosocial environment. Also, studies of outcome–environment associations involving the use of various forms and translated versions of learning environment instruments across many countries were reviewed in the chapter.

The review of literature in this chapter also established the value of assessing the efficacy of educational innovations in terms of their effect on classroom environments. This review identified which classroom environment instruments have been used in assessing the effectiveness of innovative programs across many nations. In some studies, learning environment criteria differentiated between alternative programs when student outcomes were similar between programs.

The review of literature in Section 2.4.3 of this chapter showed that the investigation of sex differences in classroom environment has revealed some interesting differences between elementary and high-school students. Females typically showed slightly more favorable perceptions of their science classroom environments than males.

This chapter also reviewed literature on the importance and assessment of students' attitudes towards science, especially literature on the Test of Science Related Attitudes (TOSRA). Research using TOSRA across many countries was reviewed because TOSRA was drawn upon for scales for my study. Studies of associations between learning environments and students' attitudes also were reviewed.

The global shift towards inquiry-based learning has become a focus of some classroom environment research. Therefore, this chapter introduced theoretical and conceptual frameworks of inquiry learning based on constructivist epistemologies. The review of literature in this chapter identified some significant constructivist practices in inquiry-based classroom environments, and these were the foundations for the development and adoption of New Generation Science Standards (NGSS). This chapter also discussed the applications, significance and limitations of inquiry-based learning and evaluated the inclusion of inquiry in the national standards. Included in this literature review was a summary of the essential features of inquiry, requirements and implementation guidelines of inquiry learning, and the essential features and challenges to inquiry practices.

The next chapter describes details of the methodological approach to my study. In Chapter 3, the research design is described in detail. Also, a detailed description of the instruments used in this study, the sample, and the methods of data collection and analysis are included in Chapter 3.

Chapter 3

RESEARCH METHODOLOGY

3.1 Introduction

Chapter 1 introduced the thesis, outlining the background of the research and its theoretical framework. It also described trends in educational reform in the United States. Chapter 2 reviewed literature pertinent to my research.

This study focused on students' attitudes and perceptions of their science classroom environment. The study maintained a focus on the fundamental principles of effective research by selecting and modifying preexisting classroom environment and attitude instruments. Because there are multiple and interwoven classroom determinants that affect outcomes which this study could not cover, it was necessary to focus on some key variables relating to the topic under investigation. The selection and adoption of the scales for this research were based on previous research by Taylor, Fisher and Fraser (1997) using the Constructivist Learning Environment Survey (CLES), and on the What Is Happening In this Class? (WIHIC) (Fraser, Fisher & McRobbie, 1996). Scales from these two instruments were carefully selected to form the Inquiry-Based Learning Environment Survey (IBLES). Also this study adopted scales from the Test Of Science Related Attitude (TOSRA) (Fraser, 1981).

Past studies have reported three approaches to classroom environment research (Fraser, 1994, 1998c): firstly, the use of trained observers to encode classroom behaviors; secondly, the use of specially-designed questionnaires to assess students' perceptions of their classroom environment; and thirdly, the use of ethnographic data-collection methods. While the first two approaches utilize quantitative data, the last approach utilizes qualitative techniques. Fraser and Walberg (1991) noted that there are significant reasons why classroom environment research often involves assessing students' perceptions of their classroom environments. Students' perceptions of their classroom environments are directly associated with the observable variation in students' learning outcome and also provides an effective tool in improving classroom environments (Fraser, 1986). Associations between learning environment variables and student outcomes have consistently been found (Fraser, 1998a). From the review of past literature in the previous chapter, it is obvious the classroom environment has a significant impact on students' cognitive and affective outcomes (Fraser, 1994).

Inquiry-based practices in the U.S. public school systems, particularly in science education, have been taken for granted for decades and minimal effort has been invested towards evaluating their usefulness until now. One intriguing question that most researchers and science educators are trying to unravel is understanding how inquiry learning practices within the classroom environments contribute to science learning (NRC, 2005). Traditional laboratory practices rarely incorporate reflections and discussions among the teacher and students. Therefore, this study was designed to investigate inquiry practices that take place in science classrooms and their effectiveness. Four principal research questions provided the anchor for this investigation:

1. Is it possible to develop valid and reliable measures of inner-city high-school Biology and Earth Science students':
   c. perceptions of inquiry-based classroom learning environments
   d. attitudes towards science?

2. Is inquiry-based instruction effective in terms of students':
   c. perceptions of learning environment
   d. attitudes towards science?

3. Is inquiry-based instruction differentially effective for male and female students in terms of:
   a. perceptions of learning environment
   b. attitudes towards science?

4. Are there associations between students' perceptions of inquiry-based learning environments and their attitudes towards science?

The description of my research methodology presented in this chapter includes the procedures, scope, design and instruments used in the study. This chapter also outlines the methods used in analysis and interpretation of data collected during this study. To address these objectives, the research is divided into five overlapping sections, namely:

Section 3.2	Research design
Section 3.3	Data sources and instrumentation
Section 3.4	Data-collection procedures
Section 3.5	Data analysis and interpretation
Section 3.6	Summary of the chapter.

3.2 Research Design

This study used an ex post facto design to compare the perceptions and attitudes of students in inquiry-based science classrooms and traditional teacher-centred science laboratory classrooms. Although studies that combined both qualitative and quantitative approach tend to produce independent results that complement each other (Tobin & Fraser, 1998), my study used only quantitative data source obtained from questionnaires. The questionnaires were used to assess students' perceptions of their science learning environment and attitudes towards science. A relatively large sample responded to the Inquiry-Based Learning Environment Survey (IBLES) and Test of Science Related Attitudes (TOSRA). Two research groups were identified for this study: the first was an experimental group which comprised science classrooms where inquiry-based practices took place; and the second group was a control group for which science instruction and laboratory activities involved the use of teacher-centred traditional methods. When I asked control-group teachers about the teacher-centred instructional methods that they commonly used, they replied that they used direct instruction, project methods and teacher-directed laboratory activities.

The non-equivalent control group helped to minimize the potential of selection bias affecting the results (Trochim & Land, 1982). Data-collection methods were carefully designed in order to minimize the possibility of group selection being atypical of a given population. The research setting for this research utilized existing intact classrooms and their teachers, therefore, maintaining the classrooms' natural location and student composition (Anderson, 1998).

3.3 Data Sources and Instrumentation

Data for this study were based on the IBLES and TOSRA questionnaires. Details of these questionnaires are discussed in the following sections. Analyses of data collected with these questionnaire provided answers to my research questions.

3.3.1 Instrumentation and Validation

As noted in Section 2.3 of Chapter 2, quite a number of instruments have been extensively validated and used in studies of students' perceptions of their classroom environment. A contribution of my research has been the selection and assembling of existing questionnaire scales that were salient to the purposes of my study and suitable for assessing students' perceptions of their inquiry-based science classrooms, and then cross-validating them in a different context. Because my investigation was focused on assessing students' perceptions and attitudes in inquiry-based science classrooms, scales from two extensively-used classroom environment instruments and one attitude instrument were selected for this study. Details of past studies involving the development and application of classroom environment and attitude instruments are discussed in Chapter 2's literature review.

The two classroom environment instruments adopted for this research were the What Is Happening In this Class? (WIHIC) (Fraser, Fisher & McRobbie, 1996) and the Constructivist Learning Environment Survey (CLES) (Taylor, Fisher & Fraser, 1997). The attitude survey used was the Test Of Science Related Attitudes (TOSRA) (Fraser, 1981). These instruments have been widely validated and found to be reliable in assessing different classroom environments and attitudes in United States public school system and have been cross-culturally validated in many countries (Fraser, 2012). My study therefore provides another context in which to confirm the validity and reliability of scales from CLES, WIHIC and TOSRA. For the purpose of this investigation, three scales were selected from each classroom environment instrument to form the Inquiry-Based Learning Environment Survey (IBLES). Similarly, three scales were initially selected for use from the original TOSRA.

3.3.2 What Is Happening In this Class? (WIHIC)

The WIHIC brings parsimony to the field of learning environments by combining modified versions of the most salient scales from a wide range of existing questionnaires with additional scales that accommodate contemporary educational concerns such as equity and cooperation. Literature pertinent to research involving the use of the WIHIC was reviewed in Chapter 2 (Section 2.3.6), but a few remarks regarding the development of WIHIC are worth mentioning in this chapter.

The WIHIC has been widely used to measure psychosocial aspects of the classroom learning environment across many countries (Fraser, 2012). Aldridge et al. (2006) noted that the robust nature of the WIHIC and its reliability and validity have been widely reported in studies that have used the instrument in different subject areas, at different age levels and in many countries, such as Singapore (Chionh & Fraser, 2009), Australia and Taiwan (Aldridge & Fraser, 2000), Brunei (Khine & Fisher, 2001), Canada (Zandvliet & Fraser, 2004), Australia (Dorman, 2001), Indonesia (Fraser, Aldridge & Adolphe, 2010), Korea (Kim, Fisher & Fraser, 2000), the United States (Allen & Fraser, 2007), and Canada, England and Australia (Dorman, 2003).

The What Is Happening In this Class? (WIHIC), developed by Fraser, Fisher, and McRobbie (1996), combines scales from different modified versions of preexisting classroom environment instruments and additional scales that are concerned with contemporary educational goals. The questionnaire has undergone a series of modifications and refinements for use across various learning groups. The WIHIC consists of 56 items in 7 scales (Aldridge & Fraser, 2000; Fraser, Fisher, & McRobbie, 1996). The seven scales are Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, and Equity. Each scale contains eight items with frequency responses ranging from Almost Never to Almost Always. Students are asked to rate each item based on their perceptions of the classroom learning environment.

The modified version of WIHIC, adapted by Aldridge, Fraser and Huang (1999) from the original version developed by Fraser, Fisher and McRobbie (1996), was used in my study in conjunction with other scales to assess students' perceptions of science classroom environments. The WIHIC has a Personal form and a Class form that measure, respectively, the perceptions of students at the personal and class level. The Personal form of the instrument was selected for this study as opposed to the Class form because it asks the student for his/her individual perceptions of his/her role in the class. Previous studies have shown that the personal form is suitable for investigation of the classroom environment perceptions of within-class groupings, such as gender subgroups (McRobbie, Fisher & Wong, 1998). The actual form of the WIHIC was used for this study in order to assess students' actual experiences of inquiry practices in their science classrooms. Table 3.1 describes the scales in the Personal form of the WIHIC by providing a sample questions for each scale. The questions are worded to address individual student's perceptions of the classroom.

Scales from WIHIC were carefully selected to assess those characteristics that were relevant to inquiry-based classroom environments in my study. Three WIHIC scales were identified and selected: Student Cohesiveness, Teacher Support, and Involvement. Table 3.2 shows the scales of WIHIC selected for this study together with two sample questions for each scale. Items are responded to using a five-point frequency scale (namely, Almost Never, Seldom, Sometimes, Often, and Almost Always).

3.3.3 Constructivist Learning Environment Survey (CLES)

The original version of the CLES developed by Taylor and Fraser (1991) was designed to assess students' perceptions of the constructivist orientation of classrooms. This instrument has been widely validated and used in a number of studies involving constructivist learning environments (Aldridge, Fraser & Sebela, 2004; Mvududu, 2003; Nix, Fraser & Ledbetter, 2005; Paucharearn & Fisher, 2004; Taylor, Dawson and Fraser, 1995; Taylor, Fraser & Fisher, 1997). The original version of CLES developed by Taylor and Fraser (1991) was guided by several criteria:conceptual foundations; a response format that assesses individual students' perceptions of their classroom; and economy of use so that the CLES can be answered in a relatively short time. A review of past research involving the CLES was provided in Section 2.3.5 of Chapter 2.

Table 3.1 Scale Description and Sample Question for Each Scale of WIHIC

Scale	Description	Item
Student Cohesiveness	Extent to which students are friendly and supportive of each other.	I make friendship among students in the class.
Teacher Support	Extent to which teacher helps, befriends, and is interested in students.	The teacher takes a personal interest in me.
Involvement	Extent to which students have attentive interest, participate in class, and are involved in other students in assessing the viability of new ideas.	I discuss ideas in class.
Investigation	Extent to which there is emphasis on the skills and of inquiry and their use in problem solving and investigation.	I carry out investigations to test my ideas.
Task orientation	Extent to which it is important to complete planned activities and stay on the subject matter.	Getting a certain amount done is important.
Cooperation	Extent to which students cooperate with other during activities.	I cooperate with other students when doing assignment work.
Equity	Extent to which the teacher treats students equally, including distributing praise, question distribution, and opportunities to be included in discussions.	The teacher gives as much attention to my question as to other students' questions.

Adapted from Fraser, Fisher and McRobbie (1996)

Table 3.2 Sample Questions for Each WIHIC Scale Chosen for my Study

Scale	Sample Questions
Student Cohesiveness	I make friendships among students in this class.
	I know other students in this class.
Teacher Support	The teacher takes a personal interest in me.
	The teacher goes out of his/her way to help me.
Involvement	I discuss ideas in class.
	I give my opinions during class discussions.

Earlier studies provided insights into the conceptual soundness and psychometric structure of the CLES and whether students made sense of the questionnaire. Despite the successful validation of the original version of CLES across numerous nations, Taylor et al. (1997) reported that the theoretical foundation on which the original CLES was formed was weak. Therefore, the CLES underwent rigorous modifications and validation in assessing different classroom environments. Taylor et al. (1997) developed another version of the instrument that incorporated a critical constructivist and radical theory component of the classroom environment. Aldridge et al. (2000) noted that the socio-cultural limitations inherent in the previous version affected students' cognitive constructive ability.

Table 3.3 Scales of the CLES and their Descriptions

Scale	Description
Personal Relevance	Extent to which teachers relate science to students out-of-school experiences
Student Negotiation	Extent to which opportunities exist for students to explain and justify their ideas to other students, and to test the viability of their newly developing ideas and to listen and reflect on the viability of other students ideas.
Shared Control	Extent to which students are invited to share with the teacher control of the learning environment, including the articulation of their own learning goals, design and management of their learning activities and determining and applying assessment criteria
Critical Voice	Extent to which a social climate has been established in which students feel that it is legitimate and beneficial to question the teacher's pedagogical plans and methods and to express concerns about any impediments to their learning.
Uncertainty of Science	To ascertain the extent of opportunities for students to experience scientific and mathematical knowledge and how it was socially and culturally determined.

(Taylor et al., 1997; Aldridge et al., 2000)

The CLES has been useful in assisting teachers and researchers to understand and obtain measures of students' perceptions in constructivist learning environments and how individual classroom practices are consistent with constructivist epistemology (Taylor, Fraser & Fisher, 1997). Taylor et al. (1997) designed the new version of CLES to measure five key elements of a critical constructivist learning environment from the students' perspective. Taylor and his colleagues observed that the new instrument provided a clear psychometric structure. Communication between teacher and student was the fundamental goal in the development of the revised CLES that contained 30 items in 5 scales, with 6 items in each scale and with five frequency response alternatives. In considering the importance of critical components of constructivism, Taylor et al. (1997) named the 5 scales of the CLES as Personal Relevance, Shared Control, Critical Voice, Student Negotiation and Uncertainty. Table 3.3 describes the five scales of the CLES.

Only some of the scales from the revised CLES were selected as being centrally relevant for the purposes of my research: Personal Relevance, Critical Voice and Student Negotiation. Table 3.4 provides sample items for the three dimensions of CLES selected for this study. A five-point frequency scale consists of Almost Never, Seldom, Sometimes, Often, and Almost Always.

Table 3.4 Sample Questions for Each CLES Scale Chosen for my Study

Scale	Sample Questions
Personal Relevance	I learn about the world outside of school.
	My new knowledge starts with problems about the world outside of school.
Critical Voice	It's OK for me to ask the teacher "Why do I have to learn this?"
	It's OK for me to question the way I'm being taught.
Student Negotiation	I get the chance to talk to other students.
	I talked to other students about how to solve problems.

3.3.4 Inquiry-Based Learning Environment Survey (IBLES)

The Inquiry-Based Learning Environment Survey (IBLES) combines scales from the WIHIC and the CLES that were carefully selected for my study to address specific psychosocial characteristics within the science classroom environment. Both instruments have undergone extensive validation around the world and across different socio-cultural backgrounds and different educational levels. Combining these scales provided significant information about students' perceptions of their inquiry-based classrooms environment. Appendix A provides a complete copy of the IBLES, which contains 42 items in 6 scales. The first three scales from the WIHIC (Fraser, Fisher, & McRobbie, 1996) contain 8 items each. The last three scales from the CLES (Taylor, Fraser & Fisher, 1997) consist of 6 items in each scale. All the 42 items of IBLES have a 5-point frequency response scale: Almost Never, Seldom, Sometimes, Often, and Almost Always.

3.3.5 Assessing Students' Attitudes to Science Using Test of Science-Related Attitudes (TOSRA)

The Test of Science-Related Attitudes (TOSRA) was designed to measure seven distinct science-related attitudes among secondary school students (Fraser, 1981). The original TOSRA was carefully developed and extensively field tested and was shown to be highly reliable when assessing students' attitudinal responses to their science learning experiences. Fraser (1981) identified these scales as 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 (1994) reported significant relationships between the quality of the classroom environment and students' attitudes.

Over the years, several studies have supported the efficacy of TOSRA for assessing students' attitudes towards science, cross-validated it, and used it in studies of associations between students' outcomes and perceptions of their classroom environment (Khine & Fisher, 2001; Kim, Fisher & Fraser, 2000; Fraser, Aldridge, & Adolphe, 2010; Lin & Crawley, 2006; Stolarchuk & Fisher, 1998; Quek, Wong & Fraser, 2005a). Wood (1998) reported a positive relationship between students' attitudes, their personal effort and their achievement in high-school classrooms in West Virginia using specialized educational software. Lin and Crawley (2004) validated the TOSRA in association with the Learning Environment Inventory (LEI) in a study of over 80 mixed-gender Taiwanese students. In Australia, Stolarchuk and Fisher (1998) observed a correlation between students' attitudes to their use of laptop computers and learning outcomes using TOSRA in conjunction with the Questionnaire on Teacher Interaction (QTI). In Singapore, Quek, Wong and Fraser (2005a) validated the TOSRA among gifted students in chemistry classrooms. Also, in Australia and Indonesia, Fraser et al. (2010) further validated the TOSRA in conjunction with WIHIC questionnaire. Past research involving the use of TOSRA was reviewed in Section 2.5.2 of Chapter 2.

The attitude scales used in my study consisted of 30 items divided equally among three scales selected from the original TOSRA (Fraser, 1981). These scales were carefully selected for use in assessing students' attitudinal responses in my study. The scales chosen were Attitude to Scientific Inquiry, Enjoyment of Science Lessons, and Social Implications of Science. All 30 items were positively-worded and scored using a five-point Likert response scale consisting of:

Strongly Agree
Agree
Not Sure
Disagree
Strongly Disagree.

TOSRA was administered simultaneously with the IBLES questionnaire in my study to save administration time. During the administration of this questionnaire, students were informed of the change from the frequency response alternatives for learning environment items to the agreement response above for attitude scales. As was the case in the classroom environment instrument, unanswered items were scored 3. Students with six or more unanswered questionnaire items were discarded from my sample. A copy of the TOSRA items used in my research is contained in Appendix B.

3.4 Data-Collection Procedures

3.4.1 Privacy, Ethical, and Statutory Considerations

This study focused on assessing high-school science classrooms in the County of Los Angeles, California. In this investigation, students and teachers from three high schools were selected based on the schools' approval to conduct research in these areas. At first, my request to conduct research in one of the school districts was declined. It took another two years to obtain approval to conduct research in two high schools from the district. The selection of these schools was primarily based on accessibility and proximity of the research population to the researcher. Following an informal discussion with some of the administrators from these schools, their verbal consent and commitment to assist encouraged me to proceed with the schools.

At Curtin University, the Human Research Ethics Committee (HREC) is responsible for the review of research proposals involving human participants. Curtin's guidelines for the operation of a two-tier system for approving research involving human participants permits ethics approval in cases where a project is low risk and raises no significant ethical issues. Because all projects granted ethics approval in the second tier must be reported to the Human Research Ethics Committee, it was necessary to obtain ethical clearance first before commencing the research study. Following the review of my Form C application, approval to conduct research was granted by the Human Research Ethics Committee (HREC) at Curtin University. A copy of the approval letter is attached in Appendix C.

Based on HREC guidelines for ethical and privacy issues at Curtin University, a consent form was given to every student in each participating classroom. All electronic data were sent to the Science and Mathematics Education Centre of Curtin University to be stored in a digital data bank for seven years. At the end of seven years, the data will be destroyed.

Prior to the commencement of this study, letters of request to conduct research were sent to seven school districts in Los Angeles County. Two school districts granted approval for the research and provided supporting letters signed by the districts' representatives. A copy of the letter of request to conduct research is attached in Appendix D. Next, the district's Letter of Approval was supported by the principal's Letter of Request to Conduct Research at a School Site. The letter contained a request to use the school facilities, teachers and the students as participants for this study. A copy of the principal's letter of permission is attached in Appendix E. A significant inclusion in the letter was that schools were informed that the results of this research would be communicated to them.

Students were provided with a parents' information sheet together with a consent letter as a first step in notifying parents regarding the study. The letter contained information about any reasonable and foreseeable risk and discomfort, as well as addressing concerns that might arise as a result of this investigation. Because this phase of the study involving the administration of the questionnaires coincided with the school's Back to School Night Program when parents meet and interact with the teachers, some of the consent letters were signed during this period. To ensure a wider range of coverage of the student population, the researcher made contact with some parents via school email to obtain verbal consent. However, a small number of students from the sampling group were excluded from this study because of reasons ranging from parents' refusal to sign the consent letter or inability to obtain a signed copy of the consent from students. A copy of parents' consent form is shown in Appendix F.

Although teachers' participation was entirely voluntary, they were provided with written information explaining details of the aims and procedures for the research. Students' and teachers' letters of consent contained a guarantee of confidentiality and protection of all statutory rights and privacy for all participating students and teachers.

Prior to administration of the questionnaire, students were also informed of the aims and objectives of the study and any specific concerns and questions were addressed by the administering teachers and the researcher. Students were also notified that they could choose not to participate at any time during the course of this investigation. The content, students' rights, and issues of privacy and confidentiality, as well as the implications of the study, were explained to students and contained in the letter of consent sent to parents.

Based on the approval from the school administration to proceed with the research, on my first meeting with the science teachers from the participating schools, I introduced the purposes of the study and requested volunteers for teacher participation. Nine teachers agreed to participate in the study. Because this research was an evaluation study, two groups were identified: an experimental group and a control group. Five teachers including myself participated as an experimental group for which inquiry practices were implemented. The other four teachers comprised the control group. All the teachers who participated in the study were provided with a teacher's information sheet, including a section that they would sign and return to the researcher. A copy of the teachers' information sheet is attached in Appendix F.

The teachers' roles in this study were:

- to monitor the administration of the questionnaire
- to assist in collating the questionnaires after completion
- to make a conscious effort to maintain effective inquiry-based practices throughout the investigation process.

It was a tedious task to convince some teachers to participate because most of them were not willing to change their daily routine of instruction or add more activities to their already tight schedule. While the selection of teachers was random, their roles in this study were primarily based on individual teaching experience with inquiry-based instruction and on personal choice. Teachers were provided with a copy of the goals and objectives of this research, their roles, and the procedures for data collection, which was attached to their letter of consent. Teachers were advised to encourage their students to participate, without co-opting them with rewards or compensation for participating in order to avoid the Hawthorne effect (Gillespie, 1991). The nine teacher volunteers consisted of four earth science and five biology teachers. Science teaching experience ranged from 4 to 22 years.

Some of the participating science teachers had received some form of training in inquiry learning as part of the district's organized professional development programs. However, in all of these schools, there were still some teachers who were reluctant to use inquiry in their classrooms and who were uncertain about the likely outcomes of inquiry learning. This attitude among these teachers created serious concerns about the confidence and effectiveness expected from these teachers for successful inquiry lessons. As part of statutory requirements, all records obtained from students, teachers, schools, and the district were treated as confidential. In order to maintain the anonymity and confidentiality of the data collected, students were identified using pseudonyms or codes (Richards & Schwartz, 2001).

3.4.2 Selection of Class and Classroom Demographics

The first semester of the 2013/2014 school year began late in August and this period was when the first phase of data collection for this research commenced. Data gathering began during September 2013 to January 2014, thus providing ample time and opportunity for the schools to complete their class scheduling process.

This study focused on earth science and biology students in grade 9 through 12. A total of 35 science classes consisting of 15 earth science classes and 20 biology classes were involved, with 15 classes in the control group (7 earth science classes and 8 biology classes) and 20 classes in the experimental group (12 earth science classes and 8 biology classes). In all of the three schools, each participating teacher had five classes corresponding to five instructional periods. Teachers were solely responsible for selecting specific class periods for investigation. Because the generalizability of findings was central to this investigation, students were selected to cover a wider range of diverse student learning groups, such as accelerated learning students, English Language Learners (ELL) including non-English speakers, mainstreamed special-education students, and students with disabilities immersed into regular classrooms. For the English Language Learners (ELL students) and non-English speakers, an instructional aide was assigned to this group of students to translate questions and provide a communication link between the students and the teachers.

3.4.3 Sampling Procedures

A total of 1,396 high-school biology and earth science students in grades 9–12, participated in this study. Figure 3.1 depicts the relative proportions of biology and earth science students within the sample. The chart shows that 54.0% of students were from biology classes while 46.0% of students were from earth science classes.

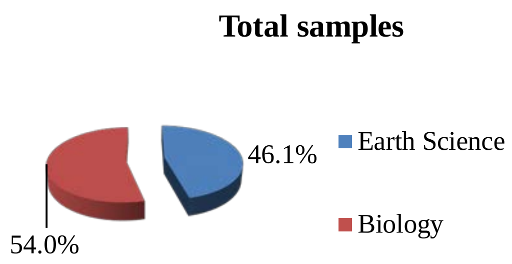

Figure 3.1 Relative Sample Sizes for Earth Science and Biology

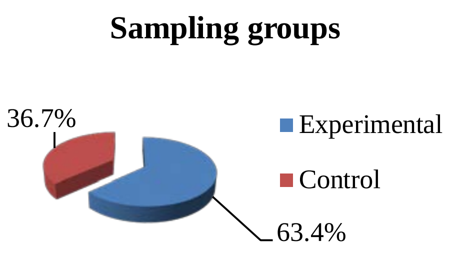

Figure 3.2 Relative Sample Sizes of Experimental and Control Groups

The experimental and control groups varied in size. Of the total of 1,396 students, 885 students were in the experimental inquiry-based group, while 512 students were in the control group for which traditional methods of laboratory investigation were being used. Figure 3.2 shows that 63.4% of the students participated in the experimental group, while 36.7% of the students participated in the control group. Two accelerated 9th grade classes were included in this study as part of the experimental group. Careful consideration was given to ensuring that group selection and data-gathering procedures involved minimal threats to external and internal validity. The distribution of the total sample according to grade level, science subjects and student sex is provided for the control group in Table 3.5 and for the experimental group in Table 3.6.

Table 3.5 Composition of the Sample by Gender, Grade Level and Science Subject for the Control Group

Grade	Total Sample		Earth Science		Biology	
	Male	Female	Male	Female	Male	Female
9	27	29	10	7	17	22
10	103	76	43	38	60	38
11	100	89	46	34	54	55
12	44	42	16	22	28	20
Total	274	236	115	101	159	135

Table 3.6 Composition of the Sample by Gender, Grade Level and Science Subject for the Experimental Group

Grade	Total Sample		Earth Science		Biology	
	Male	Female	Male	Female	Male	Female
9	41	39	15	7	26	33
10	144	127	84	89	60	38
11	142	134	94	86	48	48
12	132	125	58	46	74	79
Total	459	425	251	228	208	198

Figure 3.3 compares the experimental and control groups with respect to the percentage distribution of students between grade levels. The gender distribution is somewhat similar across all the schools sites investigated. Figures 3.4 and 3.5 represent the distribution of male and female students between biology and earth science classrooms. A total of 733 male students completed the questionnaire (representing 52.5% of the sample) and 663 female students responded to the questionnaire (representing 47.5% of the sample).

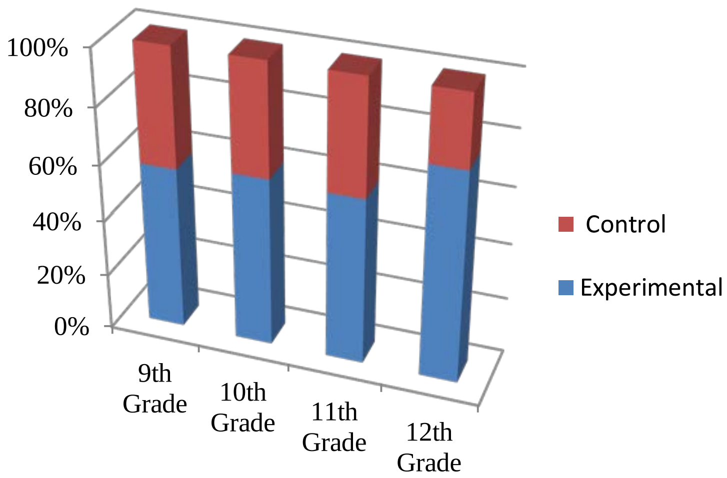

Figure 3.3 Proportion of Different Grade Levels for Experimental and Control Group

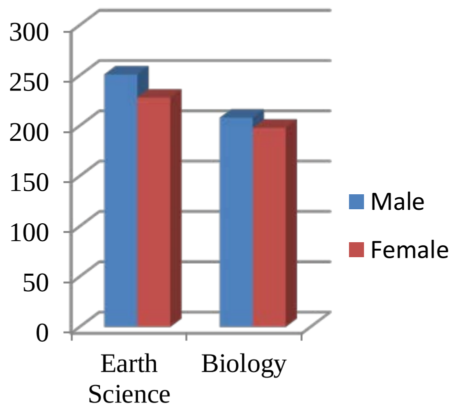

Figure 3.4 Number of Male and Female Students in Earth Science and Biology for the Experimental Group

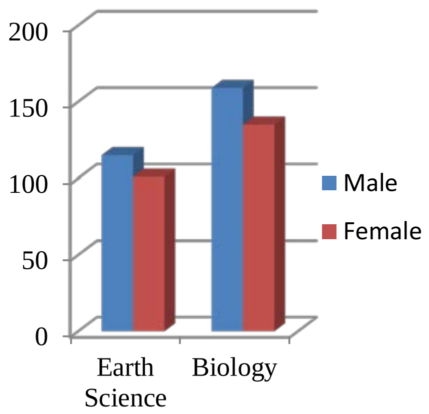

Figure 3.5 Number of Male and Female Students in Earth Science and Biology for the Control Group

3.4.4 Administration of the Questionnaire

Teachers assumed the sole responsibility for administering, collating, and collecting responses to the questionnaire from students. Prior to completing the survey, the directions for answering the questionnaire were explained to the students. In addition, students were required to complete the preliminary section containing questions about gender, grade level, subject, teacher's name, and date. Each questionnaire was coded with a numerical identification number ranging from 001 to 2,000 using each class attendance list. From the class list, the number assigned to each completed questionnaire was correspondingly entered into the data spreadsheet besides the student's name. Students were given 10–15 minutes to complete the questionnaire. However, because of the inclusion of English Language Learners

(ELL) and non-English speakers, extra time was provided to this group of students for completing the questionnaire.

The classroom environment instrument (IBLES) and the attitude survey (TOSRA) were administered to 1,396 students. The data obtained from these questionnaires were encoded solely by the researcher using Microsoft Excel spreadsheet 2010. Prior to data input, all completed questionnaires were manually checked. During the process of encoding, it was discovered that 11 students' questionnaire responses did not meet the criteria for inclusion and, hence, were discarded. This was because some of the questionnaires had many unanswered questions. During encoding, items without a response, as well as items for which two answer choices were selected, were scored 3. All completed questionnaires collected from the 15-class control group and 20-class experimental group were encoded with numerical labels and checked for accuracy and completeness. Figure 3.6 is a descriptive flow chart summarizing the data-collection method and research design for this study.

As noted later in Section 5.5, when administering the questionnaires, a small number of teachers failed to ensure that students provided the demographic information (e.g. gender) requested. Questionnaires with missing information were discarded.

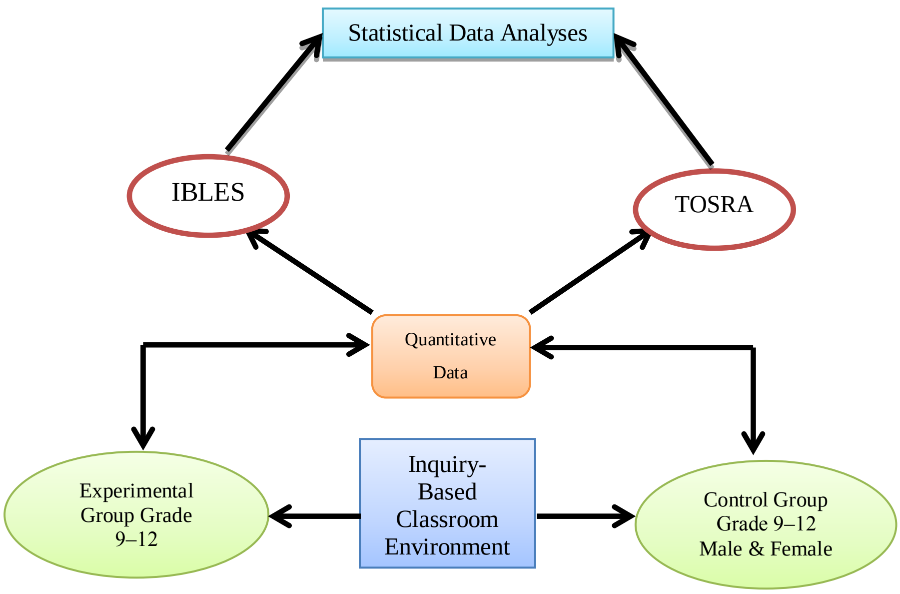

Figure 3.6 Flowchart Summarizing the Design and Method for This Research

3.5 Data Analysis and Interpretation

Analyses of the questionnaire data obtained from this investigation focused on answering the four research questions for the 1,396 high-school science students who responded to the classroom environment instrument (IBLES) and attitude instrument (TOSRA). Prior to the commencement of data analysis, a statistical analysis was performed to check the quality of the data (Patrick & Ryan, 2003). This process allows the examination of the data using statistical computation of frequency, class means, standard deviations, skewness, and maximum and minimum scores for each IBLES and TOSRA. Measures of variability and central tendency were also examined using mode, median, mean, range and standard deviation for the data. All analyses were conducted using SPSS Version 18.

3.5.1 Research Question #1: Validation of the IBLES and TOSRA Questionnaires

The first research question was: Is it possible to develop valid and reliable measures of high-school science students' perceptions of their biology and earth science classroom environments and science-related attitudes in an inner-city urban school district? To determine the validity of the IBLES and TOSRA questionnaires, I assessed the learning environment with three 8-item scales from the WIHIC (Student Cohesiveness, Teacher Support and Involvement) and three 6-item scales from the CLES (Personal Relevance, Critical Voice, and Student Negotiation). My attitude questionnaire initially consisted of three 10-item scales from the TOSRA (Social Implications of Sciences, Attitude to Scientific Inquiry and Enjoyment of Science Lessons). The sample for validity analyses consisted of 1396 students in 35 classes in 3 schools as described in Section 3.4.2.

I began by checking the factor structure for each of my questionnaires. Principal axis factor analysis with varimax rotation and Kaiser normalization was conducted using individual student as a unit of analysis. In essence, factor analysis was undertaken to determine if each questionnaire's *a priori* factor structure was supported. The two criteria for retention of any item were that it must have a factor loading of not less than 0.40 on its own scales and less than 0.40 on all other scale. Next, to check whether every item in each IBLES and TOSRA scales assessed a similar construct, the internal consistency reliability was calculated using the Cronbach alpha coefficient with individual student as a unit of analysis.

3.5.2 Research Question #2 Involving Differences between Instructional Methods and Research Question #3 Involving Whether Instructional-Method Differences are Different for Males and Females

My second research questions focused on a comparison of the experimental group with the control in terms of learning environment perceptions and attitudes. My third research question involved whether any differences existing between instructional methods were similar or different for male and female students. To answer research questions #2 and #3, both were investigated simultaneously by conducting a two-way MANOVA with my whole sample of 1,396 students and with my three WIHIC learning environment scales, three CLES learning environment scales, and two attitude scales as the set of eight dependent variables and with instructional method and sex as the independent variables. The MANOVA results for instructional and sex differences for the eight learning environment and attitude scales provided valuable information about statistically significant differences between groups. It also helped to identify the presence of an instruction–sex interaction for each environment and attitude scale, which was taken to indicate that instruction was differentially effective for male and female students. Using Wilks' lamda criterion, if the MANOVA results produced statistically significant difference between instructional methods and sexes, then the two-way univariate ANOVA results would be interpreted separately for each of the eight dependent variables.

Cohen (1998) suggested that effect sizes are necessary to describe the magnitudes or educational significance of any existing differences between the two groups. In order to determine the effect size for instructional or sex differences for a given scale, Cohen's *d* (the difference between the means of two groups divided by the pooled standard deviation) was calculated. The effect size conveniently expresses a difference between two groups in standard deviation units. According to Cohen (1998), effect sizes range from small (0.2) to medium (0.5) to large (0.8). Cohen's *d* is used when reporting my results in Chapter 4.

3.5.3 Research Question #4: Outcome–Environment Associations

The fourth research question states: Are there associations between students' perceptions of inquiry-based learning environments and their attitudes towards science? To explore relationship between students' attitudes and their perceptions of inquiry-based classroom environments, simple correlation and multiple regression analyses were performed using the individual as a unit of analysis. Simple correlation describes the bivariate association between each scale of IBLES and each attitude scale. Multiple correlation describes the relationship between an attitude scale and the set of all learning environment scales. To determine which of the scales of IBLES contributed most to this multivariate association, the standardized regression coefficients (β) were used to provide information about which environment scales contributed significantly to the variance in students' attitudes when all other environment scales were mutually controlled.

3.6 Summary of Chapter 3

The chapter provided a description of the methods used to answer my four research questions, the research design, the selection of scales for the environment and attitude questionnaire, the sample, and data-analysis methods for each research question.

Section 3.1 revisited the four research questions involving the validity and reliability of the environment and attitude questionnaires, differences between instructional methods, whether instructional-method differences are different for males and females, and association between learning environment and students' attitudes to learning.

Section 3.2 described the research design used for this study. An ex post facto design was used to compare inquiry and non-inquiry-based instructional methods. The research setting for this study was also described in this section.

Section 3.3 discussed the data sources, including the selection and assembling of the instruments used in this study. Scales pertinent for my research were carefully selected from the WIHIC and the CLES to form the IBLES. Three scales from the WIHIC (Student Cohesiveness, Teacher Support, and Involvement) and three scales from the CLES (Personal Relevance, Critical Voice, and Student Negotiation) were combined to form the environment questionnaire, while three scales from the TOSRA (Attitude of Scientific Inquiry, Enjoyment of Science, and Social Implications of Science) were initially included for this study. The sample for this study consisted of 1,396 grades 9–12 biology and earth science students (733 males and 663 females) from 35 classrooms (20 inquiry-based classrooms and 15 non-inquiry-based classrooms) in Los Angeles County, California.

Section 3.4 described the data-collection procedures, as well as the ethical and statutory considerations involved in obtaining school districts', school sites' and parents' approval. Also, school and classroom demographics, the role of teachers, and the guidelines and procedures for administration of the questionnaires were also described in this section.

To answer research question #1, the validity and reliability of the scales of IBLES and TOSRA selected for this investigation were checked using the principal axis factor analysis with varimax rotation and Kaiser normalization. The two criteria for retention of any item were that it must have a factor loading of not less than 0.40 on its own scale and less than 0.40 on all other scales. Next, scale internal consistency reliability was checked for every scale using Cronbach alpha reliability coefficient.

To answer research questions #2 and #3, a two-way multivariate analysis of variance (MANOVA) was conducted to determine if the use of inquiry-based instruction was effective and if it was differentially effective for males and females in terms of students' perceptions and attitudes. If Wilks' lambda criterion produced statistically significant multivariate differences between instructional methods and sexes, the two-way univariate ANOVA would be interpreted separately for each of the eight dependent variables. The results of this analysis are reported in Chapter 4, Section 4.3. Cohen's *d* was used to describe the magnitude of instructional or sex differences in standard deviation units.

To answer research question #4, simple correlation and multiple regression analyses were conducted to determine the relationship between students' perceptions of their learning environments and their attitudinal outcomes. Simple correlation analysis examined the bivariate relationship between each student attitude scale and each of the six learning environment scales from IBLES. Multiple regression analysis was used to determine the joint influence of the set of correlated learning environment scales on each attitude scale. Next, standardized regression coefficients were used to provide information about which environment scales contributed significantly to the variance in students' attitudes when all other environment scales were mutually controlled.

Chapter 4 reports the results obtained from the analyses of questionnaire data and uses these results to answer my four research questions. These results are described quantitatively using tables and graphs.

Chapter 4

DATA ANALYSES AND RESULTS

4.1 Introduction

My study involved the administration of comprehensively-validated scales to assess classroom environment drawn from the WIHIC (Kim, Fisher & Fraser, 2000; Koul & Fisher, 2003) and the CLES (Johnson & McClure, 2000; Kim, Fisher & Fraser, 1999; Nix, Fraser, & Ledbetter, 2005), and to assess attitudes drawn from the TOSRA (Fraser, 1978, 1981; Fraser & Lee, 2009). This chapter presents the data analyses and results that answer each of the following research questions of my study:

a. Firstly, is it possible to develop valid and reliable measures of high-school science students' perceptions of inquiry-based classroom learning environments and their attitudes towards science?
b. Secondly, is inquiry-based instruction effective in terms of students' perceptions of learning environment and attitudes towards science?
c. Thirdly, is inquiry-based instruction differentially effective for male and female students in terms of perceptions of learning environment and attitudes towards science?
d. Fourthly, are there associations between students' perceptions of inquiry-based learning environments and their attitudes towards science?

To answer the first research question involving the validity and reliability of my questionnaires, analyses of data obtained from 1,396 grades 9–12 biology and earth science students in 35 classes were performed for two instruments: the Inquiry-Based Learning Environment Survey (IBLES), consisting of WIHIC and CLES scales, and the Test Of Science-Related Attitudes (TOSRA). Details of the procedures for the development of the classroom environment instrument and selection of the scales for the attitude survey were described in Section 3.3 of the previous chapter. This chapter is divided into four sections:

Section 4.2 Research Question #1: Validity and Reliability of IBLES and TOSRA

- 4.2.1 Factor Structure of Learning Environment and Attitude Scales
- 4.2.2 Internal Consistency Reliability for IBLES and TOSRA Scales
- 4.2.3 Internal Consistency Reliability of WIHIC and CLES from Past Studies

Section 4.3 Research Question #2: Differences between Instructional Methods and Research Question #3: Whether Instructional-Method Differences are Different for Males and Females

- 4.3.1 Instructional-Method Differences in Learning Environment and Attitude Scales
- 4.3.2 Sex Differences in Learning Environment and Attitude Scales
- 4.3.3 Interaction between Instructional Method and Sex

Section 4.4 Research Question #4: Associations between Learning Environment and Student Attitudes

Section 4.5 Chapter Summary.

4.2 Research Question #1: Validity and Reliability of the IBLES and TOSRA

This section is focused on answering Research Question #1: Is it possible to develop valid and reliable measures of high-school science students' perceptions of inquiry-based classroom learning environments and their attitudes towards science? As mentioned in Chapter 3, IBLES was developed by combining scales selected from the WIHIC and the CLES, but factor analysis was performed and reported separately for the WIHIC and CLES. Three 8-item scales from the WIHIC (Student Cohesiveness, Teacher Support and Involvement) and three 6-item scales from the CLES (Personal Relevance, Critical Voice, and Student Negotiation) were used to assess students' perceptions of their learning environment. Three 10-item scales from the TOSRA (Social Implications of Science, Attitude to Scientific Inquiry, and Enjoyment of Science Lessons) were initially used to assess students' attitudes to science (although one of these scales subsequently was lost during analysis as reported below).

4.2.1 Factor Structure of Learning Environment and Attitude Scales

The structure of the data was examined to determine if they supported the *a priori* factor structure. Validation of the WIHIC and CLES using confirmatory factor analysis has been reported in previous studies (Dorman, Fisher & Waldrip, 2006). To check the factor structure of the scales using SPSS, principal axis factor analysis with varimax rotation and Kaiser normalization was performed separately for the WIHIC, the CLES and TOSRA to generate orthogonal factors. The results of the factor analyses are shown in Table 4.1 for the WIHIC, Table 4.2 for the CLES and Table 4.3 for the TOSRA. Because the instrument was developed with scales from preexisting classroom environment instruments (three scales from the WIHIC and three scales from the CLES), a three-factor solution was generated for each classroom environment instrument to substantiate the structure and to reduce the data so as to minimize redundancy and manage correlations among scales (Stapleton, 1997). The criteria for the retention of any item were that it must have a factor loading of at least 0.40 with its own scale and less than 0.40 with every other scale in that questionnaire.

4.2.1.1 Factor Structure of WIHIC

Data for the three 8-item WIHIC scales were analyzed to determine the factor structure. Table 4.1 shows the results of factor analysis for the WIHIC and provides the factor loadings. Because each of the 24 WIHIC items satisfied the above two criteria for retention (i.e. having a factor loading of at least 0.40 with its own scale and less than 0.40 with the other two scales), all 24 items were retained.

Table 4.1 shows that the proportion of variance accounted for was 7.26% (Student Cohesiveness), 39.05% (Teacher Support), and 11.81% (Involvement). The total proportion of variance was 58.12%. The scale eigenvalues ranged from 1.74 to 9.37 for different WIHIC scales. Factor analysis results for WIHIC data from this study strongly supported the factorial validity of the three-scale version of WIHIC, as well as replicating the factor analysis results from much past research with the WIHIC reviewed in Sections 2.3.6 and 3.3.2.

4.2.1.2 Factor Structure of CLES

Similar to the WIHIC questionnaire, 18 CLES items in three scales were selected. Table 4.2 shows the results of factor analysis for the three scales (Personal Relevance, Critical Voice, and Student Negotiation). The two bottom rows report the percentage variance and the eigenvalue for each scale.

When factor analysis was performed for CLES data using the principal axis factor analysis with varimax rotation and Kaiser normalization, Item PR6 from the Personal Relevance scale was omitted because it did not meet the criteria for retention (namely, that any item must have a factor loading of at least 0.40 on its own scale and less than 0.40 on each of the other three CLES scales). Table 4.2 reports the factor loadings. The percentage of variance was 9.52% (Personal Relevance), 13.47% (Critical Voice), and 32.11% (Student Negotiation). The total percentage of variance for the three scales of CLES was 55.10%. The eigenvalues ranged from 1.71 to 5.77 for different CLES scales. As was the case in the WIHIC, the factor analysis of CLES items used in this study strongly supported the factorial validity of the three-scale version of CLES. And my results for the CLES are similar to factor analyses in past research reviewed in Sections 2.3.5 and 3.3.3.

4.2.1.3 Factor Structure of TOSRA

The attitude questionnaire used in my study comprised 30 items in 3 scales selected from TOSRA (Fraser, 1981): Attitude of Scientific Inquiry, Enjoyment of Science Lessons and Social Implications of Science. Each scale contained 10 items.

To determine the factor structure of the 30-item attitude questionnaire using the data obtained with 1,396 high-school science students, principal axis factoring was performed to generate the orthogonal factors. Because three scales were used, a three-factor solution was generated.

Table 4.1 Factor Analysis Results for WIHIC Scales

Item	Factor Loadings		
	Student Cohesiveness	Teacher Support	Involvement
SC1	0.68		
SC2	0.67		
SC3	0.54		
SC4	0.76		
SC5	0.58		
SC6	0.49		
SC7	0.63		
SC8	0.57		
TS1		0.69	
TS2		0.76	
TS3		0.79	
TS4		0.72	
TS5		0.62	
TS6		0.77	
TS7		0.73	
TS8		0.69	
IN1			0.67
IN2			0.74
IN3			0.57
IN4			0.64
IN5			0.59
IN6			0.68
IN7			0.54
IN8			0.57
% Variance	7.26	39.05	11.81
Eigenvalue	1.74	9.37	2.83

N=1,396 students

Factor loadings less than 0.40 have been omitted from the table.

Principal axis factoring with varimax rotation and Kaiser normalization.

Table 4.2 Factor Analysis Results for CLES Scales

Item	Factor Loadings		
	Personal Relevance	Critical Voice	Student Negotiation
PR1	0.71		
PR2	0.68		
PR3	0.51		
PR4	0.76		
PR5	0.69		
CV1		0.64	
CV2		0.74	
CV3		0.77	
CV4		0.64	
CV5		0.59	
CV6		0.54	
SN1			0.52
SN2			0.73
SN3			0.69
SN4			0.64
SN5			0.71
SN6			0.62
% Variance	9.52	13.47	32.11
Eigenvalue	1.71	2.42	5.77

N=1,396 students
Factor loadings less than 0.40 have been omitted from the table.
Principal axis factoring with varimax rotation and Kaiser normalization.

As was the case with the classroom environment scales, the factor analysis allowed checking of whether the criteria for the retention of any item were met. The factors were rotated using the varimax rotation and Kaiser normalization to maximize their variance. Some items were omitted because they did not meet the criteria of having a factor loading of 0.40 or above with their *a priori* scale and less than 0.40 on the other scales. As a result, the entire Social Implications of Science scale, as well as 4 items from Attitude to Scientific Inquiry (INQ 4, INQ6, INQ8, and INQ10), were omitted from the attitude questionnaire. Table 4.3 shows the results of the factor analysis for the attitude scales selected from TOSRA. Each of the 16 remaining items of TOSRA had a factor loading of at least 0.40 on its own scale and less than 0.40 on the other TOSRA scales.

Table 4.3 Factor Analysis Results for TOSRA Scales

Item	Factor Loadings	
	Attitude of Scientific Inquiry	Enjoyment of Science Lessons
INQ1	0.63	
INQ 2	0.41	
INQ 3	0.74	
INQ 5	0.47	
INQ 7	0.40	
INQ 9	0.47	
ENJ1		0.63
ENJ 2		0.68
ENJ 3		0.66
ENJ 4		0.66
ENJ 5		0.62
ENJ 6		0.54
ENJ 7		0.69
ENJ 8		0.64
ENJ 9		0.64
ENJ 10		0.55
% Variance	13.47	30.59
Eigenvalue	2.15	4.89

N=1,396 students
Factor loadings less than 0.40 have been omitted from the table.
Principal axis factoring with varimax rotation and Kaiser normalization.

Results of factor analysis revealed that the percentage of variance explained by Attitude of Scientific Inquiry was 13.47% and by Enjoyment of Science Lessons was 30.59%. The total proportion of variance accounted for was 44.06% as shown in Table 4.3. The eigenvalues were 2.15 for Attitude of Scientific Inquiry and 4.89 for Enjoyment of Science Lessons. These results strongly supported the two-factor structure of the refined 16-item attitude questionnaire based on scales selected from TOSRA, and replicate past factor analyses of TOSRA data reviewed in Sections 2.5.2 and 3.3.5.

4.2.2 Internal Consistency Reliability for IBLES and TOSRA Scales

Internal consistency was used as a measure of the degree of correlation between different items in the same instrument or whether items in the same instrument are measuring the same construct (Cortina, 1993). For the 1,396 science students in 35 classes, the internal consistency reliability was calculated for each of the WIHIC, CLES and TOSRA scales using Cronbach's alpha reliability coefficient.

Table 4.4 reports the scale mean, standard deviation and alpha reliability for every WIHIC, CLES and TOSRA scale. Alpha coefficients can range from 0–1.00, with the higher values representing higher internal consistency. Nunnally (1978) suggests that alpha coefficients of 0.60 or higher are considered satisfactory. Table 4.4 shows that alpha coefficients ranged from 0.86 for Students Cohesiveness to 0.92 for Teacher Support for the three WIHIC scales, and from 0.78 for Personal Relevance to 0.85 for Student Negotiation for the 3 CLES scales. For the two attitude scales, the alpha coefficient was 0.67 for Attitude to Scientific Inquiry and 0.87 for Enjoyment of Science. These reliability values compare favorably with those obtained from previous studies (Dorman et al., 2006; Kim, Fisher, & Fraser, 1999). The results shown in Table 4.4 attest to the high reliability of all learning environment and attitude scales when used with Californian high-school science students.

Table 4.4 Scale Mean, Standard Deviation, and Internal Consistency Reliability (Cronbach Alpha Coefficient) for IBLES and TOSRA

Scale	No of Items	Mean	SD	Alpha Reliability
IBLES				
Student Cohesiveness	8	3.53	0.76	0.86
Teacher Support	8	2.89	1.05	0.92
Involvement	8	2.81	0.87	0.89
Personal Relevance	5	3.32	0.85	0.78
Critical Voice	6	3.33	0.95	0.83
Student Negotiation	6	3.49	0.86	0.85
TOSRA				
Science Inquiry	6	2.56	0.73	0.67
Science Enjoyment	10	2.95	0.79	0.87

N= 1,396 students

4.2.3 Internal Consistency Reliability of WIHIC and CLES in Past Studies

The purpose of this section is to compare the scale reliability values found in my study with those reported in past studies in various countries as reviewed in Sections 2.3.5 and 2.3.6. Table 4.5 shows a comparison of alpha reliability coefficients for past studies with the WIHIC and Table 4.6 shows similar comparison of alpha coefficient for past studies with the CLES.

Table 4.5 shows that WIHIC has been successfully used and validated in many countries. In United States, Allen and Fraser (2007) validated the WIHIC with 520 grade 4 and 5 students and 120 parents from 22 elementary classes in Miami. Pickett and Fraser (2010) also validated the WIHIC in a study conducted in Florida with 573 grades 3–5 students in 33 classes. Den Brok et al. (2006) also used the WIHIC with 665 middle-school science students in California. Ogbuehi and Fraser (2007) validated the WIHIC using 661 junior high-school students from 22 mathematics classes. Martin-Dunlop and Fraser (2007) validated the WIHIC using 525 science students from 27 classes in California. Wolf and Fraser (2008) validated the WIHIC using 1,434 middle-school science students in 71 classes in New York. In Canada, Raaflaub and Fraser (2013) validated the WIHIC using 1,127 mathematics and science students.

In Australia, Britain and Canada, Dorman et al. (2011) reported the validity of WIHIC scales using 3,602 grades 8–12 science students. In another study conducted in Australia and Canada, Fraser and Zandvliet (2004, 2005) validated the WIHIC with 1,404 high-school students in 81 technology-rich classes. In India, Koul and Fisher (2005) validated the WIHIC using 1,021 students from 32 science classes. In Taiwan and Australia, Aldridge, Fraser and Huang (1999) validated the WIHIC using 1,081 grade 8 and 9 science students. In Singapore, the WIHIC has been validated in a study conducted by Chionh and Fraser (2009) using a large sample of 2,310 grade 10 students from 75 mathematics and geography classes, and by Khine and Fisher (2001) with 1188 students. Shadreck (2012) validated the WIHIC using 1,728 junior secondary school students in 10 school districts in Zimbabwe.

Table 4.5 Comparison of Cronbach Alpha Reliability Coefficients for WIHIC Scales in My Study and in Past Research

Study	Sample Size	Alpha Reliability Coefficient		
		Student Cohesiveness	Teacher Support	Involvement
Present study	1,396 grades 9–12 students	0.86	0.92	0.89
Florida (Allen & Fraser, 2007)	520 grades 4–5 students	0.67	0.80	0.74
USA (Pickett & Fraser, 2010)	573 grades 3–5 students	0.57	0.73	–
California (den Brok et al., 2006)	655 junior high students	0.77	0.89	0.86
California (Ogbuehi & Fraser, 2007)	661 Junior high students	–	–	0.81
California (Martin-Dunlop & Fraser, 2008)	525 science students	0.86	0.94	–
New York (Wolf & Fraser, 2008)	1,434 junior high students	0.80	0.92	0.86
Canada (Raaflaub & Fraser, 2013)	1,173 high school students	0.76	0.85	0.84
Australia, Britain and Canada (Dorman et al., 2011)	3,602 grades 8–12 students	0.83	0.84	0.79
Australia and Canada (Zandvliet & Fraser, 2005)	1,404 high-school students	0.86	–	0.86
India (Koul & Fisher, 2005)	1,021 students	0.58	0.78	0.76
Taiwan (Aldridge, Fraser & Huang, 1999)	1,081 science students	0.81	0.88	0.84
Singapore (Chionh & Fraser, 2009)	2,310 grade 10 students	Geography 0.90 Mathematics 0.90	Geography 0.88 Mathematics 0.89	Geography 0 .88 Mathematics 0.87
Singapore (Khine & Fisher, 2001)	1,188 students	0.78	0.80	0.80
Zimbabwe (Shadreck, 2012)	1,728 junior high	0.80	0.88	0.89
Korea (Kim, Fisher & Fraser, 2000)	543 students	0.82	0.87	0.90
Indonesia and Australia (Fraser, Aldridge & Adolphe, 2010)	1,161 science students	Indonesia 0.82 Australia 0.81	Indonesia 0.88 Australia 0.82	Indonesia 0.85 Australia 0.78
Indonesia (Wahyudi & Treagust, 2003)	1,400 science students	0.68	0.78	0.81
Turkey (Telli et al., 2006)	1983 grade 9 and 10 students	0.75	0.86	0.80
UAE (MacLeod & Fraser, 2009)	763 science students	–	0.85	0.91
South Africa (Aldridge, Fraser &Ntuli, 2009)	1,077 grade 5–7 students	0.69	0.68	0.69

In Korea, Kim, Fisher and Fraser (2000) validated the WIHIC with 543 science students. In Indonesia, Fraser et al. (2010) validated an Indonesian version of the WIHIC with 594 junior high-school science students, and Wahyudi and Treagust (2003) validated the WIHIC with 1,400 science students. Telli et al. (2006) reported strong validity and reliability for the WIHIC in a study with 1983 grade 9 and 10 students in Turkish secondary schools. In the UAE, MacLeod and Fraser (2009) used 1,400 science students to validate the WIHIC. In South Africa, Aldridge, Fraser and Ntuli (2009) also validated the WIHIC with 1,077 grades 5–7 mathematics students.

As with the WIHIC questionnaire, results from studies conducted with CLES have provided consistent evidence about validity and reliability worldwide and across different disciplines. Table 4.6 reports the reliability of CLES scales in studies conducted in the United States, Australia and United Kingdom, Singapore, Nigeria, Thailand, South Africa, Korea, and other nations. The alpha coefficients reported in my study replicate the results from the previous studies in Table 4.6.

Table 4.6 Comparison of Cronbach Alpha Reliability Coefficients for CLES Scales in My Study and in Past Research

Study	Sample Size	Alpha Reliability Coefficient		
		Personal Relevance	Critical Voice	Students Negotiation
Present Study	1,396 high school students	0.78	0.83	0.85
California (Ogbuehi & Fraser, 2007)	661 junior high students	0.71	–	0.83
United States (Johnson & McClure, 2000)	127 college students	0.80	0.83	0.91
Texas (Nix, Fraser, & Ledbetter, 2005)	1,079 grade 9–12 students	0.75	0.77	0.85
Florida (Spinner & Fraser, 2002)	118 grade 5 students	0.83	0.78	0.84
Australia and USA (Taylor, Fraser & Fisher, 1997)	1,600 grade 9–12 science students	0.70	0.82	0.89
Australia, Britain and Canada (Dorman et al., 2003, 2011)	3,602 grades 8–12 students	0.76	–	0.80
Australia (Dorman, Adams and Ferguson, 2006)	4,146 high school students	0.78	0.80	0.80
South Africa (Aldridge et al., 2004)	1,864 junior high students	0.61	–	0.63
Korea (Kim et al., 1999)	1083 high school students	0.78	0.80	0.87
Korea (Lee & Fraser, 2000)	439 high school students	0.78	0.80	0.84
Iran (Eskandari & Ebrahimi, 2013)	415 university students	0.72	0.83	0.80
Thailand (Puacharearn, 2004)	606 upper secondary students	0.84	0.81	0.85
Nigeria (Idiris& Fraser, 1994)	1,175 secondary science students	0.55	–	–
Singapore (Koh & Fraser, 2014)	2,261 high school students	0.76	0.78	0.84
Singapore (Choo, 2011)	333 grade 5 students	0.64	0.75	0.82

In California, Ogbuehi and Fraser (2007) validated the CLES with 661 middle-school student from 22 mathematics classes. Also in United States, Johnson and McClure (2000) validated the CLES with 127 college students, while Nix, Fraser and Ledbetter (2005) validated a new Comparative Student version of the CLES with 1,079 students from 59 classes in Texas. In Florida, Spinner and Fraser further established the validity and reliability of the CLES with 118 grade 5 students. In Australia, Taylor, Fraser and Fisher (1997) used a large sample of 1,600 high school science student to validate the CLES. In a similar study, Dorman, Adams and Ferguson (2006) further confirmed the validity and reliability of the CLES with 4,146 high-school students. Also in Australia, Britain and Canada, Dorman et al. (2011) reported the reliability of the CLES using a large sample of 3,602 grades 8–12 students. In South Africa, Aldridge, Fraser and Sebela (2004) cross-validated the CLES with 1,864 intermediate and senior-level students in 43 classes from six schools. In Korea, Kim, Fisher and Fraser (1999) validated the CLES using 1,083 high-school science students in 24 classes from 12 schools. Also in Korea, Lee and Fraser (2000) validated the CLES with 439 high school students from different streams. In Iran, Eskandari and Ebrahimi (2013) validated a Persian version of CLES with 415 Iranian university students in 17 chemistry classes. In Thailand, Puacharearn and Fisher (2004) validated a Thai version of the CLES with 606 science students in upper-secondary school. In Nigeria, Idiris and Fraser (1994) validated the CLES in agricultural science classrooms using 1,175 students in 50 classes. In Singapore, Koh and Fraser (2014) validated the CLES with 2,261 high-school students. Also, in Singapore Choo (2011) used the CLES with 333 students in grade 5 classrooms.

4.3 Research Question #2: Differences between Instructional Methods and Research Question #3: Whether Instructional-Method Differences are Different for Males and Females

In this section, the effectiveness of inquiry-based learning in terms of classroom environment and students' attitude to science is reported. Once the validity and reliability of the research instruments were established, the data were then used to answer the three remaining research question as stated in Chapters 1 and 3. My second research question focused on a comparison of the experimental group with a control group in terms of learning environment perceptions and attitudes. My third research question involved whether any differences existing between instructional methods were similar or different for male and female students.

Both of these research questions were investigated simultaneously by conducting a two-way MANOVA with my whole sample of 1,396 students in 35 classes and with the six IBLES learning environment scales and two TOSRA attitude scales as the set of eight dependent variables. Instructional method and student sex were the two independent variables. As mentioned in Chapter 3, Section 3.4.3, 63.5% of the 9–12 grade students who participated in the study received instruction using inquiry-based practices while 46.5% received instruction using traditional laboratory methods. The presence or absence of a statistically significant interaction between instructional method and sex was used to identify whether instructional-method differences were different or similar for males and females.

Initially conducting MANOVA for the entire set of eight dependent variables reduced the Type I error rate associated with conducting separate univariate tests for individual dependent variables. Using Wilks' lamda criterion, MANOVA revealed significant results for instructional method and sex. Therefore I was justified in interpreting the ANOVA results separately for each of the eight dependent variables. Table 4.7 provides the two-way ANOVA results for instructional method, sex and the instruction–by–sex interaction separately for each learning environment and attitude scale. The F value from ANOVA (a test of the statistical significance of a difference between groups) is provided for each dependent variable.

Table 4.7 shows that statistically significant results emerged for: instructional method for every learning environment scale and both attitude scales; and for sex for the three learning environment scales of Student Cohesiveness, Teacher Support and Critical Voice (but for neither attitude scale). However, instruction−by−sex interactions were statistically nonsignificant for all learning environment and attitude scales.

Table 4.7 ANOVA Results (*F*) for Instructional Method and Sex Differences in Learning Environment and Attitude Scales

Scale	Instruction *F*	Sex *F*	Instruction x Sex *F*
IBLES			
Student Cohesiveness	30.36**	28.44**	0.11
Teacher Support	289.95**	6.59**	0.18
Involvement	130.68**	0.93	0.00
Personal Relevance	23.42**	0.98	0.97
Critical Voice	14.51**	10.44**	0.95
Student Negotiation	35.44**	2.50	0.03
TOSRA			
Science Inquiry	11.73**	0.87	0.41
Enjoyment of Science	72.78**	0.05	2.23

Males (n = 735) and Females (n = 661), Experimental (n = 886), Control (n = 510)
**p<0.01

4.3.1 Instructional-Method Differences for Learning Environment and Attitude Scales

Table 4.8 provides for each learning environment and attitude scale, the average item mean, the average item standard deviation, and the ANOVA results repeated from Table 4.7. The average item mean is simply the scale mean divided by the number of items in a scale. Table 4.8 also provides an effect size for the instructional-method difference for each scale. Cohen's *d* is the difference between the means for the two instructional methods divided by the pooled standard deviation for each learning environment and attitude scale. The effect size conveniently expresses a difference between two groups in standard deviation units. According to Cohen (1988), effect sizes range from small (0.2) to medium (0.5) to large (0.8)

Table 4.8 shows that, for all eight scales, instructional-method differences were statistically significant. Furthermore, scores were less favorable for the control group than for the experimental group for every scale. That is, relative to students in the control group, students in inquiry-based classrooms perceived a more positive classroom environment on all WIHIC and CLES scales and had higher scores on both attitude scales. For these scales, effect sizes ranged from 0.22 to 0.39 standard deviations, which are in the small range according to Cohen's (1988) criteria for most scales with the exception of Involvement (medium effect of 0.63 SDs) and Teacher Support (large effect of 0.93 SDs).

Table 4.8 Average Item Mean, Average Item Standard Deviation and Instructional Group Difference (ANOVA Result and Effect Size) for Each Learning Environment and Attitude Scale

Scale	Item Mean		Item SD		Difference	
	IBL	Control	IBL	Control	*F*	Effect Size (*d*)
IBLES						
Student Cohesiveness	3.81	3.38	0.73	0.79	30.36**	0.30
Teacher Support	3.22	2.31	0.89	1.06	289.95**	0.93
Involvement	3.00	2.47	0.81	0.87	130.68**	0.63
Personal Relevance	3.41	3.17	0.79	0.92	23.42**	0.23
Critical Voice	3.40	3.19	0.91	1.00	14.51**	0.22
Student Negotiation	3.59	3.31	0.81	0.92	35.44**	0.32
TOSRA						
Science Inquiry	3.49	2.65	0.68	0.79	11.73**	0.39
Enjoyment of Science	3.19	2.82	0.74	0.83	72.78**	0.23

Experimental (n = 886), Control (n = 510)
Cohen's d = (difference in means)/pooled SD
**$p<0.01$

Figure 4.1 is a visual representation of the differences between inquiry-based classrooms and traditional non-inquiry-based classrooms using the average mean of the environment and attitude scales. The graph shows that the average item mean for the experimental group ranged from 3.00 to 3.81 for the environment scales and was 3.19 to 3.49 for the attitude scales. The mean scores for the control group ranged from 2.31 to 3.38 for the environment scales and was 2.65 to 2.82 for the attitude scales. Referring to the response alternative used in the questionnaire, inquiry-based classrooms' scores correspond to frequencies of between Sometimes and Often, while the traditional non-inquiry-based classrooms' scores correspond to a frequency of between Seldom and Sometimes.

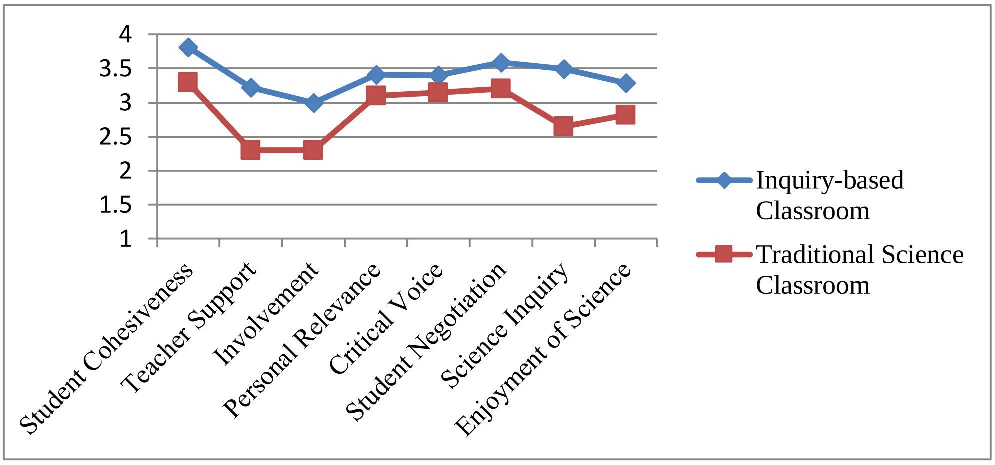

Figure 4.1 Comparison of Inquiry-based Classrooms with Non-Inquiry-based Classrooms in Terms of Learning Environment and Attitude Scales

Based on the results shown in Table 4.8, the item mean and effect sizes were found to be consistent with those obtained from past studies that examined students' perceptions of inquiry-based learning conducted at the classroom level. Overall, students in inquiry-based learning environments perceived their classrooms more favorably than those in traditional science classrooms (Choo, 2011; Devitt, 2005; Martin-Dunlop & Fraser, 2008; Wolf & Fraser, 2008).

4.3.2 Sex Differences for Learning Environment and Attitude Scales

Sex differences in IBLES and TOSRA scores are reported in this section. Table 4.9 provides the two-way ANOVA results (repeated from Table 4.7) and effect sizes for sex differences in the eight learning environment and attitude scales. The table reports the average item mean and the average item standard deviation for male and female subgroups.

Table 4.9 Average Item Mean, Average Item Standard Deviation and Sex Difference (ANOVA Result and Effect Size) for Each Learning Environment and Attitude Scale

Scale	Item Mean		Item SD		Difference	
	Females	Males	Females	Males	*F*	Effect Size (*d*)
IBLES						
Student Cohesiveness	3.65	3.42	0.74	0.76	28.44**	0.31
Teacher Support	2.97	2.81	1.05	1.04	6.59**	0.15
Involvement	2.78	2.82	0.88	0.86	0.93	-0.05
Personal Relevance	3.29	3.34	0.86	0.84	0.98	-0.06
Critical Voice	3.41	3.25	0.95	0.94	10.44**	0.17
Student Negotiation	3.53	3.45	0.87	0.85	2.50	0.09
TOSRA						
Science Inquiry	3.42	3.46	0.74	0.72	0.87	-0.05
Enjoyment of Science	3.04	3.06	0.76	0.82	0.20	-0.03

Males (n = 735) and Females (n = 661)
Cohen's d = (difference in means)/pooled SD
**p<0.01

The results shows that sex differences were statistically significant for three scales (Student Cohesiveness, Teacher Support and Critical Voice) for which effect sizes ranged from 0.15 to 0.31 standard deviations, which would be classified as small according to Cohen's (1988) criteria. Interestingly, for three scales for which sex differences were statistically significant, females held somewhat more favorable perceptions than males. Figure 4.2 is a visual representation of the differences between the perceptions and attitudes of male and female students in terms of their classroom environment and attitudes. The graph shows that female students perceived their classroom environment to be somewhat more cohesive than the male students did, as well as making friends and knowing other students relatively better than males. Also females worked well with other students and tended to assist others students in class. The result further revealed that, relative to males, female students perceived that teachers tended to take a personal interest in students and go an extra mile to help students.

On the other hand, male students perceived somewhat more frequently than female students that science learning is more relevant to outside their lives in school and that scientific concepts and ideas have influenced people and culture over time. Figure

4.2 also shows that male students perceived their classroom environments slightly more favorably than females in terms of attitudes towards scientific inquiry.

From these analyses, it is evident that female students perceived their classroom environments more favorably than the male students in terms of Student Cohesiveness, Teacher Support and Critical Voice. These results for sex differences are consistent with past studies (Goh & Fraser 1996; Khine & Fisher, 2001; Kim, Fisher & Fraser, 2000; Koul & Fisher, 2005; Riah & Fraser, 1998; Wahyudi & Treagust, 2004b; Wong & Fraser, 1994).

For instructional-group differences (Table 4.8), all environment and attitude scales showed statistically significant differences with effect sizes ranging from 0.22 for Critical Voice to 0.93 for Teacher Support. For sex differences (Table 4.9), the magnitudes of the differences for the scales which showed statistically significant sex differences (Student Cohesiveness, Teacher Support and Critical Voice) were relatively small and ranged from 0.15 to 0.31 standard deviations. Therefore, the magnitudes of sex differences in my study were smaller than the magnitude of instructional differences, as further illustrated in Figures 4.2 and 4.3.

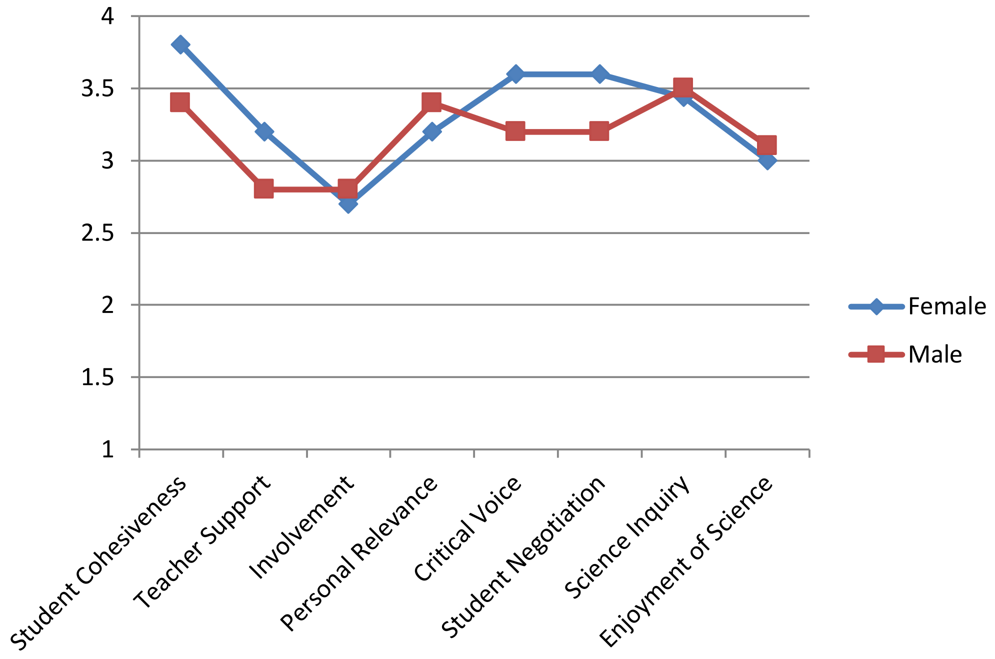

Figure 4.2 Comparison of Male and Female Students in Terms of Learning Environment and Attitude Scales

4.3.3 Interaction between Instructional Method and Sex

Table 4.7 shows how the results of the two-way ANOVAs can be used to determine if there were differences in the effectiveness of using inquiry-based learning for males and females. The results show that the instruction−by−sex interaction was statistically nonsignificant for every learning environment and attitude scale. This suggests that the above interpretation of results separately for instructional method (Table 4.8) and sex (Table 4.9) are valid and meaningful. The use of inquiry-based learning was not differentially effective for males and females for any of the environment or attitude scales, which answers my third research question.

4.4 Fourth Research Question #4: Associations between Learning Environment and Student Attitudes

My fourth research question involved associations between students' perceptions of six aspects of classroom environment (Student Cohesiveness, Teacher Support, Involvement, Personal Relevance, Critical Voice, Student Negotiation) and two attitude scales (Attitude to Scientific Inquiry, Enjoyment of Science Lessons). Data from my sample of 1,396 students were used. This section reports results for associations between students' perceptions of their learning environment and attitudes.

To investigate the relationships between students' perceptions of their learning environment and student attitudes, simple correlation and multiple regression analyses were conducted. Simple correlations (r) described the bivariate relationship between each student attitude scale and each of the six learning environment scales from IBLES. Multiple regression analysis was conducted to determine the joint influence of the set of correlated learning environment scales on each attitude scale. The multiple correlation *(R)* was used to describe the multivariate association between an attitude scale and the set of all learning environment scales. Standardized regression coefficients (β) were used to provide information about which environment scales contributed significantly to the variance in students' attitudes when all other environment scales were mutually controlled.

Table 4.10 provides the simple correlation between each learning environment scale and each student attitude scale. All of the six IBLES scales showed a statistically significant correlation with Attitude to Scientific Inquiry. For Attitudes to Scientific Inquiry, correlations ranged from 0.08 (Student Cohesiveness) to 0.13 (Student Negotiation). For Enjoyment of Science, correlations were statistically significant for every learning environment scale except Critical Voice. Significant correlations ranged from 0.11 (Student Cohesiveness) to 0.29 (Teacher Support). Higher learning environment scores were linked to higher Inquiry and Enjoyment scores.

For each attitude scale, the multiple correlation with the set of six environment scales was statistically significant. The multiple correlation for the sets of IBLES scales and Attitudes to Science Inquiry was 0.16 and for Enjoyment of Science was 0.34. Inspection of the regression coefficients revealed that:

- Student Negotiation was a positive independent predictor of Attitude to Scientific Inquiry.
- Each of the six WIHIC and CLES scales was a positive independent predictor of Enjoyment of Science.

Interestingly, all statistically significant univariate and multivariate associations in Table 4.10 are positive, suggesting that there was a positive relationship between environment scales and students' attitudes. These results replicate considerable past research that provides convincing evidence that classroom environment is a strong determinant of students' attitudes towards science (Fraser, 2012).

Table 4.10 Simple Correlation and Multiple Regression Analyses for Associations between Learning Environment and Attitude Scales

Scale	Attitude–Environment Association			
	Attitude to Inquiry		Enjoyment of Science	
	r	*β*	*r*	*β*
IBLES				
Student Cohesiveness	0.08**	0.00	0.11**	0.07*
Teacher Support	0.10**	0.04	0.29**	0.20**
Involvement	0.10**	0.01	0.25**	0.12**
Personal Relevance	0.11**	0.04	0.19**	0.08**
Critical Voice	0.09**	0.04	0.04	0.09**
Student Negotiation	0.13**	0.07*	0.22**	0.12**
Multiple Correlation *R*		0.16**		0.34**

$^{*}p<0.05$, $^{**}p<0.01$

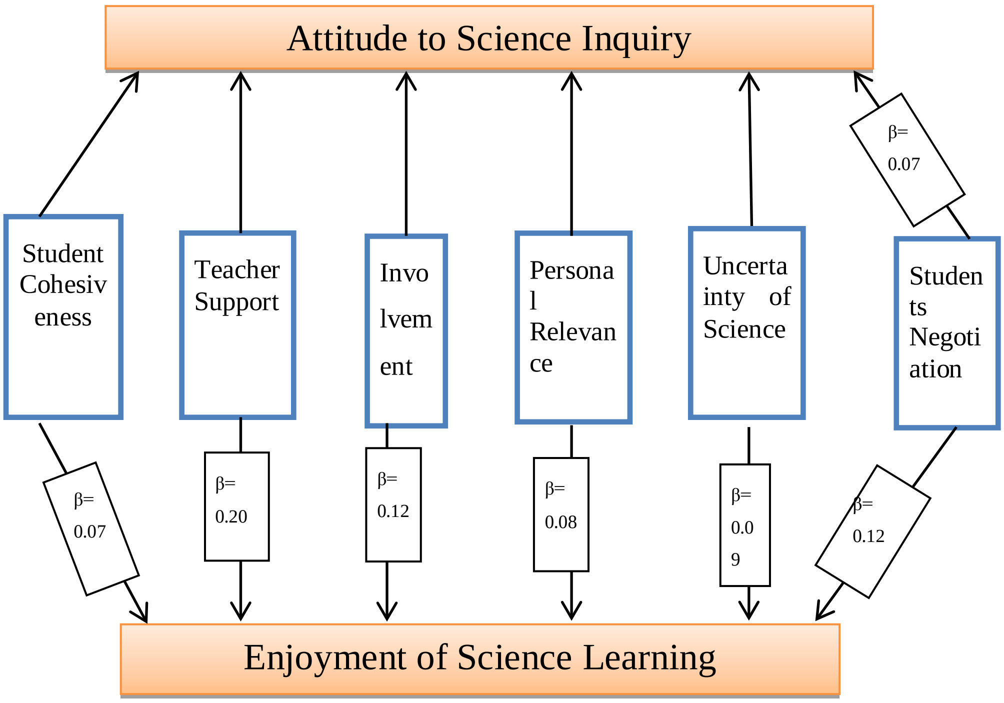

Figure 4.3 Classroom Environment Scales that Contributed Uniquely and Significantly to Variance in Two Attitude Scales Using Standardized Regression Coefficients (β)

Figure 4.3 is a visual representation of the of environment scales that contributed significantly and uniquely to variation in students' attitudes. Beta weights indicated that all environment scales contributed significantly and independently to the variance in Enjoyment of Science Lessons, with beta weights ranging from 0.07 for Student Cohesiveness to 0.20 for Teacher Support. In contrast, Student Negotiation (β=0.07) was the only environment scale that contributed significantly and independently to Attitude to Scientific Inquiry. This results support the view that students' attitudes to science learning are closely associated with their learning environment perceptions.

Overall, the results of data analysis reported in this section suggest that there is a statistically significant association between students' perceptions of the classroom learning environment and their attitudes towards science learning. My findings are consistent with those obtained in past studies which showed positive and statistically significant relationships between students' attitudes and their classroom environment perceptions (Allen & Fraser, 2007; Fraser, Aldridge & Adolphe, 2010; Kim, Fisher

& Fraser, 2000; Martin-Dunlop & Fraser, 2008; Ogbuehi & Fraser, 2007; Quek, Wong & Fraser, 2005a; Wolf & Fraser, 2008).

4.5 Chapter Summary

This chapter focused on providing answers to my four research questions which were discussed in Chapters 1 and 3. It described the analyses of IBLES and TOSRA data from 1,396 high school students in 35 biology and earth science classrooms. The research questions are: firstly, is it possible to develop valid and reliable measures of science students' perceptions of the classroom learning environment and their attitudes towards science? Secondly, is inquiry-based instruction effective in terms of students' perceptions of learning environment and attitudes towards science? Thirdly, is inquiry-based instruction differentially effective for male and female students in terms of perceptions of learning environment and attitudes towards science? Fourthly, are there associations between students' perceptions of inquiry-based learning environments and their attitudes towards science?

This chapter began with a report of the analyses for research question 1: the validity and reliability of IBLES and TOSRA scales. The IBLES consists of six scales (three scales selected from WIHIC and three scales from CLES).Three TOSRA scales were used in the initial version of the attitude questionnaire. To examine the validity and reliability of the learning environment and attitude scales, principal axis factoring followed by varimax rotation was used to determine the factor structure. Also the internal consistency reliability was calculated for each scale with individual student as the unit of analysis. Factor analysis supported the three-scale structure of the WIHIC and the three-factor structure of CLES, but a two-scale structure for the TOSRA.

The total amount of variance accounted for was 58.12% for the WIHIC, 55.1% for the CLES, and 44.06% for TOSRA. Eigenvalues for the WIHIC scales ranged from 1.74 (Student Cohesiveness) to 9.37 (Teacher Support), and for the CLES scales ranged from 1.71 (Personal Relevance) to 5.77 (Student Negotiation). The eigenvalue for TOSRA was 2.15 for Science Inquiry and 4.89 for Enjoyment of Science.

The internal consistency reliability was determined using the Cronbach alpha reliability coefficient with the individual student as unit of analysis. The alpha coefficient for the 6 scales of IBLES ranged from 0.78 (Personal Relevance) to 0.92 (Teacher Support) and for the 2 scales of TOSRA was 0.67 (Scientific Inquiry) to 0.87 (Enjoyment of Science). The highest alpha reliability was obtained for the Teacher Support and the lowest for the scale Scientific Inquiry. These results compare favorably with those obtained from previous studies reported in Table 4.5 for the WIHIC and in Table 4.6 for the CLES scales, as well as in previous studies with TOSRA (Fraser et al., 2010; Wong & Fraser, 1996).

Next, the chapter reported the effectiveness of inquiry-based instruction in terms of students' perceptions and attitudes. Data from 1,396 students were analyzed using a two-way MANOVA with instructional method (inquiry-based classrooms vs. non-inquiry-based classrooms) and student sex as the independent variables. Using Wilks' lambda criterion, MANOVA revealed significant results for instructional method and sex for the set of dependent variables as a whole, and therefore the two-way ANOVA results were interpreted separately for each learning environment and attitude scale. Statistically significant results emerged for: method of instruction for every learning environment scale and both attitude scales; and for sex for three learning environment scales but not for attitudes. Although instructional-method differences were statistically significant for all scales, effect sizes were moderate or large only for Involvement (0.63 SDs) and Teacher Support (0.93 SDs) according to Cohen's (1988) criteria.

Sex differences were statistically significant for three environment scales (Student Cohesiveness, Teacher Support and Critical Voice) for which effect sizes were small and ranged from 0.15 to 0.31 standard deviations. Interestingly, the results show that females held somewhat more favorable perceptions than males for these three scales.

Two-way MANOVA was used to determine if there were differences in the effectiveness of using inquiry-based learning for males and females. The results showed that the instruction–by–sex interaction was statistically nonsignificant for every learning environment and attitude scale and, therefore, the use of inquiry-based learning was not differentially effective for males and females for any scale.

Next, associations between students' perceptions of their classroom learning environment and their attitudes toward science were reported. Simple correlation and multiple regression analyses were used to explore associations between the learning environment scales and each student attitude scales. Simple correlation analysis revealed that all learning environment scales significantly correlated with Science Inquiry and that, for the Enjoyment of Science scales, all the environment scales except Critical Voice showed a positive and statistically significant correlation. Standardized regression coefficients (β) were used to provide information about which environment scales contributed significantly to the variance in students' attitudes when all other environment scales were mutually controlled. Beta weights showed that only Student Negotiation scale was statistically, significantly, and independently related to Attitude to Science Inquiry. For the Enjoyment of Science scale, all of the six environment scales were statistically significantly and independently related to Enjoyment of Science Lesson. These results suggested that improved student attitudes are associated with more emphasis on the aspects of learning environment assessed in this study.

Chapter 5 summarizes the thesis and draws on previous chapters to present an overview, as well as a detailed discussion, of the major findings obtained. It describes the implications of the research and the effectiveness of inquiry-based learning in Californian public schools education system. The chapter concludes with consideration of the limitations of the present study and provides recommendations for subsequent studies on inquiry-based practices in science classrooms.

Chapter 5

DISCUSSION AND CONCLUSION

5.1 Introduction

This chapter concludes this thesis which reports an evaluation of inquiry-based learning among 1,396 high-school biology and earth science students from 35 classes in Los Angeles County public schools. My study focused mainly on how students' attitudes and perceptions of their classroom environments differ according to instructional method (inquiry and non-inquiry-based learning) and student sex.

The State of California and Local Education Agencies (LEA) have adopted new science standards designed on the premise of inquiry and constructivist practices. Therefore, this study used data obtained from quantitative sources using IBLES (based on scales from WIHIC and CLES) and TOSRA. The study provided insight into how students' perceptions and attitudes differed under alternative instructional methods. Also associations between various aspects of classroom environment and students' attitudes were reported. The conclusions presented in this chapter are organized under the following headings:

Section 5.2 Overview of the Thesis
Section 5.3 Major Findings of the Study
Section 5.4 Significance and Implication of the Findings for Educational Practice
Section 5.5 Constraints and Limitations of the Study
Section 5.6 Suggestions and Recommendations for Further Research
Section 5.7 Concluding Remarks.

5.2 Overview of the Thesis

Chapter 1 introduced the background, conceptual and theoretical framework, significance and aims of the study. It also provided insight into the development of the New Generation Science Standards (NGSS) and the recent adoption of federal and state educational reforms in the USA. The four research questions which were the focus for this study were also delineated in this chapter. The four research questions are:

a. Is it possible to develop valid and reliable measures of science students' perceptions of inquiry-based classroom learning environments and their attitudes towards science?
b. Is inquiry-based instruction effective in terms of students' perceptions of learning environment and attitudes towards science?
c. Is inquiry-based instruction differentially effective for male and female students in terms of perceptions of learning environment and attitudes towards science?
d. Are there associations between students' perceptions of inquiry-based learning environments and their attitudes towards science?

Although extensive research has been conducted in the field of learning environment, Chapter 2 mainly reviewed literature pertinent to my study and presented some historical background of classroom environment research. I comprehensively reviewed literature related to the origin, development, and uses of classroom environment and attitude instruments. Determinants of students' perceptions of their classroom environments were reviewed in Chapter 2. Also, literature on students' attitudes to science, as well as past studies of associations between students' perceptions and learning outcomes, were also reviewed. The chapter concluded by presenting detailed characteristics of inquiry-based learning in science classrooms, as well as its implications and prospects in modern science classrooms in the Californian public school system.

Chapter 3 described the methods, research design, and techniques used for data collection. It also described the development and selection of environment scales for inclusion in the Inquiry-Based Learning Environment Survey (IBLES) and the attitude scales from the Test Of Science-Related Attitudes (TOSRA) used in this study. The 42-item 6-scale IBLES and the 30-item 3-scale TOSRA were used with a sample of 1,396 students in biology and earth science classrooms in Los Angeles County, California. A total of 886 students participated in classrooms where inquiry-based practices were implemented, while 510 students participated in non-inquiry-based classrooms. The sample comprised 735 male students and 661 female students.

The IBLES combines scales from the WIHIC and the CLES that were carefully selected to address specific psychosocial characteristics relevant to inquiry-based science classroom environments. Three scales from the WIHIC (Student Cohesiveness, Teacher Support and Involvement) and three scales from the CLES (Personal Relevance, Critical Voice and Student Negotiation) were selected for use in this study. From the TOSRA, the three scales of Attitude to Scientific Inquiry, Enjoyment of Science Lessons, and Social Implications of Science were selected for use in this study.

Chapter 3 also described the statistical analyses used to provide answers to my four research questions. To answer research question #1 concerning the validity and internal consistency reliability of my questionnaires, principal axis factor analysis followed by varimax rotation and Kaiser normalization was performed for my sample of 1,396 students for the 42-item 6-scale IBLES and 30-item 3-scale TOSRA to check the *a priori* factor structure. The Cronbach alpha coefficient was used with the individual student as the unit of analysis to determine the internal consistency reliability of each IBLES and TOSRA scale.

Answers to research questions #2 and #3 were obtained from a two-way multivariate analysis of variance (MANOVA) performed with the six scales of IBLES and two scales of TOSRA as dependent variables and with instructional method and sex as the independent variables. The results from the two-way MANOVA, together with effect sizes, were also used to determine the overall effectiveness of inquiry-based instruction, as well as whether inquiry-based learning was differentially effective for males and females.

Research question #4 was answered by performing simple correlation and multiple regression analyses with the individual as unit of analysis to determine associations between students' perceptions of their classroom learning environment and their attitudes towards science. Standardized regression coefficients were used to identify which environment scales contributed uniquely to variance in student attitudes.

5.3 Major Findings of the Study

Chapter 4 provided the results for my four research questions. When data obtained from 1,396 high school science students were analyzed in numerous ways described above, the results summarized in this section were obtained.

5.3.1 Validity and Reliability of IBLES and TOSRA

Statistical analyses that were used to answer Research Question #1 included factor analysis and Cronbach alpha reliability analysis for the scales of IBLES and TOSRA. To check the *a priori* factor structure, principal axis factor analysis followed by varimax rotation and Kaiser normalisation was performed with data obtained from 1,396 biology and earth science students in 35 classes using the 6-scale IBLES and the 3-scale TOSRA. A three-factor solution was attempted for each environment instrument (WIHIC and TOSRA) and for TOSRA. The criteria for retention of any item were that it must have a factor loading of at least 0.40 on its own scale and less than 0.40 on each of the other scales in the questionnaire. The factor analysis for the three WIHIC scales showed that each of the 24 items satisfied the criteria for retention. When factor loading was performed for the scales of the CLES, Item PR6 (Personal Relevance scale) did not meet the criteria for retention and therefore was removed. Factor analysis for the 30-item TOSRA revealed that all 10 items from Social Implications of Science and 4 items from Attitude to Scientific Inquiry (INQ 4, INQ6, INQ8, and INQ10) did not meet the criteria for retention and therefore were omitted.

For the WIHIC, the total proportion of variance was 58.12% and scale eigenvalues ranged from 1.74 to 9.37. For the CLES, the total percentage of variance was 55.10% and eigenvalues ranged from 1.71 to 5.77 for different scales. For the attitude scales, the total proportion of variance accounted for was 44.06% and the scale eigenvalues were 2.15 and 4.89. Overall, the results supported the 3-scale factor structure of the WIHIC and CLES and a revised 2-scale factor structure for the TOSRA.

To check the internal consistency reliability (the degree of correlation between different items on the same test or whether items in the same scale measure the same construct),Cronbach's alpha coefficient was calculated for the 6 scales of IBLES and 2 TOSRA scales with the individual student as the unit of analysis. Alpha coefficients ranged from 0.86 (Students Cohesiveness) to 0.92 (Teacher Support) for the three WIHIC scales, ranged from 0.78 (Personal Relevance) to 0.85 (Student Negotiation) for the CLES, and were 0.67 (Attitude to Scientific Inquiry) and 0.87 (Science Enjoyment) for the TOSRA. Overall, the results show satisfactory internal consistency reliability for all the scales of IBLES and TOSRA when used to assess students' perceptions of their classrooms. These validity and reliability results are consistent with past studies conducted by Aldridge and Fraser (2000), Chionh and Fraser (2009), Ogbuehi and Fraser (2007) and Wolf and Fraser (2008).

5.3.2 Differences between Instructional Methods and Whether Instructional-Method Differences are Different for Males and Females

This section summarizes findings for the central focus of this research, which was to evaluate inquiry-based instruction in terms of students' perceptions of classroom environment and attitudes (Research Question #2). The same analysis was used to answer Research Question #3 regarding the differential effectiveness of inquiry-based instruction for male and female students. To examine instructional and sex differences, a two-way MANOVA with method of instruction and sex as the independent variables was conducted for the set of 8 environment and attitude scales as dependent variables. Initially conducting MANOVA for the entire set of eight dependent variables reduced the Type I error rate associated with conducting separate univariate tests for individual dependent variables. Using Wilks' lamda criterion, MANOVA revealed significant results for instructional method and sex. Therefore I was justified in interpreting the ANOVA results separately for each of the eight dependent variables. Also, effect sizes were calculated using Cohen's *d* (the difference between the means for the two instructional methods divided by the pooled standard deviation for each learning environment and attitude scale).According to Cohen (1988), effect sizes range from small (0.2) to medium (0.5) and then to large (0.8).

Interestingly, for all eight scales, scores were significantly less favorable for the non-inquiry-based (control group) classrooms than for the inquiry-based classrooms (experimental group). That is, relative to students in the control group, students in inquiry-based classrooms perceived a more positive classroom environment on all WIHIC and CLES scales and had higher scores on both attitude scales. For these scales, effect sizes ranged from 0.19 to 0.93 standard deviations, which are in the small range according to Cohen's (1988) criteria for most scales with the exception of Involvement (medium effect of 0.63 SDs) and Teacher Support (large effect of 0.93 SDs).

This study also examined differences between male and female students' perceptions and attitudes using samples of 735 male students and 661 female students. The two-way ANOVAs revealed that sex differences were statistically significant for three scales of IBLES (Student Cohesiveness, Teacher Support, and Critical Voice), but effect sizes were small and ranged from 0.15 to 0.31 standard deviations. Sex differences in attitude scales were small and statistically nonsignificant. Interestingly, for the three scales that showed a statistically significant difference, females' scores were higher than males' scores.

The two-way MANOVA also was used to examine the interaction between instructional method and sex. The presence or absence of a statistically significant interaction between instructional method and sex was used to identify whether instructional-method differences were different or similar for males and females. MANOVA revealed that instruction–by–sex interactions were statistically nonsignificant for the set of all learning environment and attitude scales. This implies that inquiry-based instruction was equally effective for males and females in terms of classroom environment perceptions and attitudes to science.

5.3.3 Associations between Learning Environment and Student Attitudes

To examine associations between students' perceptions of the six aspects of classroom environments (Student Cohesiveness, Teacher Support, Involvement, Personal Relevance, Critical Voice, Student Negotiation) and the two attitude scales of Attitude to Scientific Inquiry and Enjoyment of Science, simple correlation and multiple regression analyses were performed with the individual student as the unit of analysis (Research Question #3). Simple correlation analysis revealed the bivariate relationship between each student attitude scale and each learning environment scale. Multiple regression analysis examined the joint influence of the set of correlated learning environment scales on each attitude scale. Standardized regression coefficients (β) were used to provide information about which environment scales contributed significantly to the variance in students' attitudes when all other environment scales were mutually controlled.

Results of simple correlation analysis showed that all of scales of IBLES significantly and positively correlated with Attitudes to Scientific Inquiry. For Enjoyment of Science, significant positive correlations were found for Student Cohesiveness, Teacher Support, Involvement, Personal Relevance, and Student Negotiation. Also, the multiple correlation with the set of six environment scales was statistically significant for both Inquiry and Enjoyment. Inspection of the regression coefficients revealed that:

- Student Negotiation was a positive independent predictor of Attitude to Scientific Inquiry.
- Each of the six WIHIC and CLES scales was a positive independent predictor of Enjoyment of Science.

My results for the validity of classroom environment scales are consistent with much past research and therefore support Fraser's (2007) observation that "few fields of educational research can boast the existence of such a rich array of validated and robust instruments (p. 105). Furthermore, my findings are consistent with considerable past research that has investigated and reported consistent associations between students' perceptions of their classroom environment and their attitudes (Allen & Fraser, 2007; Chionh & Fraser, 2009; Fraser, 2012, 2014; Wolf & Fraser, 2008).

5.4 Significance and Implications for Educational Practice

This section considers the significance of my study and its implications for educational practice. In this study, classroom environment scales were carefully selected from the WIHIC and the CLES and attitude scales were selected from the

TOSRA and were used to evaluate inquiry-based high-school science teaching in Californian public school. Because only a relatively few studies have previously been conducted into science learning environments in California using these instruments, this study further contributed to the field of learning environments, as well as providing relevant information on how high-school students in California perceive inquiry-based science classrooms.

This study revealed that the classroom environment and attitude instruments used in this investigation have strong validity and satisfactory internal consistency reliability in assessing high-school inquiry-based science classrooms. With their strong validity and reliability, these widely-applicable instruments now can be used by other educators for a variety of purposes.

Because this study focused on the evaluation of inquiry-based science instruction, it can provide valuable information for teachers to justify adopting inquiry-based practices in their classrooms and for administrators to justify and make well-structured decisions about science instruction and curriculum. Based on the findings of this study, inquiry-based learning can be an effective strategy for improving students' perceptions of classroom environment and attitudes in science learning.

Scales for which significant sex differences emerged were Students Cohesiveness, Teacher Support and Critical Voice. For these scales, females had slightly higher scores than males. A practical implementation from these results is that teachers can anticipate that different within-class subgroups of students could have somewhat different learning environment perceptions.

However, the instructional method–sex interaction was nonsignificant and of very little educational importance for all scales. A practical implication of this result for teachers and school administrators in designing instructional activities and programs is that inquiry teaching/learning was equally effective for male and female students.

Because all six learning environment scales of the IBLES showed positive independent associations with Enjoyment of Science and the Student Negotiation scale showed a positive independent association with Attitude to Scientific Inquiry, these findings are practically relevant. Therefore, an understanding of this relationship could help teachers and school administrators to provide effective science lessons and well-structured classroom management plan.

This study provides a further justification for educators to create and maintain positive classroom climates. Considerable past research overwhelmingly confirms that positive classroom environments promote improved students outcomes.

5.5 Constraints and Limitations of the Study

Large and representative samples are always an advantage in research studies. My sample was limited to one area of Los Angeles and, of the seven schools initially contacted for this study, only three high schools from two school districts accepted my request to participate. This limited the size and representativeness of the sample to only a small geographical and ethno-cultural group, which limited the generalizability of my findings.

Some constraints and limitations were encountered during this research and were taken into consideration during data collection and analysis and the interpretation of results. One constraint was that teachers who participated in this study had different levels of skills and training in inquiry teaching. This study was conducted at the time when the districts were transitioning to Common Core and New Generation Science Standards (NGSS). Schools and classrooms were undergoing structural and curricular reorganization to accommodate these changes; new resources and computer technology were being introduced into schools and classrooms; and professional developments was being conducted on the new science standards and inquiry teaching in order to accommodate these curricula changes. However, some teachers were feeling apprehensive and uncertain about these changes and showed reluctance about making modifications to integrate inquiry-based instruction into their teaching. Some of the teachers who participated in this study were yet to receive training in inquiry-based methods on which the New Generation Science Standards were based. These uncertainties created doubts among these teachers about their likely success in implementing inquiry. Therefore, with these prevailing circumstances, it is unlikely that the best of inquiry instruction would have been practised in some of these classrooms and therefore that my findings should be generalized to all teachers with caution.

Motivating students to complete the questionnaire was also a difficult task. Some students viewed the exercise as academically non-rewarding and therefore were indifferent about completing the questionnaire. Also, the timing for administration of the questionnaire might have affected students' responses. Because some students were taking their final semester examination around the same time when the questionnaires were administered, it is likely that some students might have been reluctant to complete the questionnaires conscientiously.

A small number of teachers administered the questionnaire to the students without following the pre-administration procedures for obtaining demographic information about students. Some of these questionnaires had no indication of gender group, class or subject, school, and grade level, and therefore were discarded from my data pool. This slightly reduced my sample size.

Because the questionnaire contained 72 items that were administered during the same class period, some students might have become fatigued and lost concentration. This might have affected the quality and completeness of some questionnaire responses. This probably explained why some of the questionnaires were returned unanswered or only partially answered. These questionnaires were identified during data input and discarded.

Another constraint in this study was my inability to obtain a valid, reliable and comparable achievement measure from all participating teachers. Although teachers assessed their students at the end of the units using the district's approved criterion test pertaining to their lessons, some teachers used the school's science curriculum test guide, while others used self-generated test questions that were tied to their instruction. Also, while some teachers used multiple-choice achievement assessments, others used extended written responses and students' laboratory reports graded on a rubric scale. Because achievement tests were graded differently by different teachers, achievement test scores were considered inconsistent and invalid for this investigation. Because of the unavailability of reliable achievement test data, my study employed only attitudes as student outcome measures.

During data-collection process, the questionnaires were administered to the students only as a post-assessment towards the end of the academic semester. This posed a constraint because there was no pre-assessment data for use as a benchmark for tracking changes over time.

Although the use of quantitative data such as questionnaires provided insights into the learning environment from the students' perspective, some past studies also have shown that much useful information also can be obtained from qualitative and interpretative methods and from combining quantitative and qualitative data-collection methods (Tobin & Fraser, 1998; Tobin, Kahle, & Fraser, 1990). My investigation did not include qualitative data from classroom observations and student interviews because of problems with accessibility to the schools and classrooms and the timing of my study.

In research studies, all data collection and analytical methods have limitations, and the type of limitation depends on the research method and data analysis techniques used. For my study, some limitations associated with my methods of statistical analysis were observed during my investigation. First, because my sample size was limited, my data were analyzed using the individual student as the unit of analysis. With a larger sample, it would have been possible also to employ the class mean as the unit of analysis and to conduct more sophisticated statistical analysis such as confirmatory factor analysis or multilevel analysis.

Another limitation to this investigation was the absence of a pilot test. During the administration of the questionnaire, some students were confused about answering some of the questions. For example, for the Teacher Support scale of WIHIC, questions such as "The teacher takes a personal interest in me" and "The teacher talks with me" were repeatedly identified for clarification by the students. This difficulty probably would have been identified and rectified if pilot study had been conducted. In future research, it would be desirable to conduct a pilot study aimed at identifying and removing any confusion among students in the wording of any questionnaire items.

Another constraint worth acknowledging is that there were numerous students who were English Language Learners (ESL) from low socioeconomic background involved in the study. Some of the students completed the questionnaire with the help of their peers who were also struggling with English language fluency. This language barrier might have resulted in some of these students completing the survey without a complete understanding of the questions. This language obstacle might have resulted in frustration and fatigue among this group of students and therefore accounted for some of the unanswered questions observed in the questionnaire responses.

Also, because this study only used students of lower economic status, it is possible that students' responses in terms of their perceptions and attitudes might have been influenced by their socioeconomic background. Therefore, the results of my study might not be generalizable to students from a broader range of socioeconomic backgrounds.

5.6 Suggestions and Recommendations for Further Research

This study's limitations discussed above lead to suggestions for desirable future research directions. Because the sample for this study was obtained from a small localized section of Los Angeles County with sociocultural and economic homogeneity, it is therefore recommended that more extensive studies be conducted with larger and more diverse samples beyond the county and state frontiers. This would improve the generalizability of findings.

Tobin and Fraser (1998) suggested the importance of integrating qualitative and quantitative data sources in classroom environment research. In my study, my inability to obtain reliable qualitative data left a gap that needs to be filled in future research. More-extensive use of carefully-generated qualitative data from interviews, reflective journals, and observations could enhance the potential usefulness of the results of future studies while complementing the quantitative data sources.

In classroom environment research, researchers have puzzled over whether students studying different science subjects and at different grade levels perceive their classrooms differently? Although my study used student groups from biology and earth science classes, subject and grade-level differences were not the primary focus of this investigation. Therefore, future investigations that include exploration of subject and grade-level differences might unravel relevant and interesting information.

Also, this study used only items from the actual form of WIHIC and CLES to form the IBLES. Further studies are recommended using a combination of the preferred and actual versions of the scales. Studies of students' actual and preferred classroom environment would enhance the validity of the instrument, as well as enabling teachers to reflect on and improve instruction in their classrooms.

In my study, the inclusion of student sex as an independent variable led to the valuable insight that inquiry-based methods were equally effective for male and female students. In future research, it is recommended that the differential effectiveness of inquiry methods be investigated for other variables such as ethnicity or socioeconomic status.

In future research involving larger samples, it is recommended that the class mean is used as the unit of statistical analysis and that more sophisticated types of data analysis (e.g. confirmatory factor analysis or multilevel analysis) are undertaken.

5.7 Concluding Remarks

This chapter concluded this thesis. I evaluated inquiry teaching and investigated associations between students' perceptions of inquiry-based science classrooms and their attitudes towards science among 1,396 high-school science students from 35 biology and earth science classes in Los Angeles County. The classroom environment was assessed with six scales from the WIHIC and the CLES, whereas students' attitudes to science were assessed with two scales selected from the TOSRA.

This study is significant because it supported the effectiveness of inquiry-based teaching in terms of students' perceptions of science classroom environment and their attitudes towards science. Moreover, inquiry teaching was found to be equally effective for male and female students. All six learning environment scales were found to relate positively, independently and significantly to Enjoyment of Science Lessons, while Student Negotiation related positively, independently, and significantly with Attitude to Scientific Inquiry. This suggests that changing classroom learning environments could enhance students' attitudes towards science.

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Appendix A

Inquiry-Based Learning Environment Survey (IBLES)

Gender (Check one): Male ( ) Female ( ) Grade Level:__________
Date:____________
Class/Subject: ______________ Test ID #:_________ Primary Language______________
Ethnicity: Caucasian ( ), African American ( ), Pacific Islander ( ), Asian ( )
Native Alaskan ( ), Hispanic ( ), Hawaiian Natives ( )
Others ( )________

Directions for Students

- This questionnaire contains statements about practices that could take place in this class. You will be asked how often each practice takes place.
- There are no 'right' or 'wrong' answers. Your opinion is what is wanted and your responses will be kept confidential.
- Think about how well each statement describes what this class is like for you.

  Draw a circle around

  1 if the practice takes place Almost Never

  2 if the practice takes place Seldom

  3 if the practice takes place Sometimes

  4 if the practice takes place Often

  5 if the practice takes place Almost Always
- Be sure to give an answer for all questions. If you change your mind about an answer, just cross it out and circle another.
- Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.

Practice Example

Suppose you were given the statement "I choose my partners for group discussion." You would need to decide whether you choose your partners 'Almost always', 'Often', 'Sometimes', Seldom" Almost never'. If you selected 'Often' then you would circle the number 4 on your questionnaire.

STUDENT COHESIVENESS		Almost Never	Seldom	Some-times	Often	Almost Always
1.	I make friendships among students in this class.	1	2	3	4	5
2.	I know other students in this class.	1	2	3	4	5
3.	I am friendly to members of this class.	1	2	3	4	5
4.	Members of the class are my friends.	1	2	3	4	5
5.	I work well with other class members.	1	2	3	4	5
6.	I help other class members who are having trouble with their work.	1	2	3	4	5
7.	Students in this class like me.	1	2	3	4	5
8.	In this class, I get help from other students.	1	2	3	4	5
TEACHER SUPPORT		**Almost Never**	**Seldom**	**Some-times**	**Often**	**Almost Always**
9.	The teacher takes a personal interest in me.	1	2	3	4	5
10.	The teacher goes out of his/her way to help me.	1	2	3	4	5
11.	The teacher considers my feelings.	1	2	3	4	5
12.	The teacher helps me when I have trouble with the work.	1	2	3	4	5
13.	The teacher talks with me.	1	2	3	4	5
14.	The teacher is interested in my problems.	1	2	3	4	5
15.	The teacher moves about the class to talk with me.	1	2	3	4	5
16.	The teacher's questions help me to understand.	1	2	3	4	5
INVOLVEMENT		**Almost Never**	**Seldom**	**Some-times**	**Often**	**Almost Always**
17.	I discuss ideas in class.	1	2	3	4	5
18.	I give my opinions during class discussions.	1	2	3	4	5
19.	The teacher asks me questions.	1	2	3	4	5
20.	My ideas and suggestions are used during classroom discussions.	1	2	3	4	5
21.	I ask the teacher questions.	1	2	3	4	5
22.	I explain my ideas to other students.	1	2	3	4	5

23.	Students discuss with me how to go about solving problems.	1	2	3	4	5
24.	I am asked to explain how I solve problems.	1	2	3	4	5
	PERSONAL RELEVANCE	**Almost Never**	**Seldom**	**Some-times**	**Often**	**Almost Always**
25.	I learn about the world outside of school.	1	2	3	4	5
26.	My new knowledge starts with problems about the world outside of school.	1	2	3	4	5
27.	I learn how science can be part of my out-of-school life.	1	2	3	4	5
28.	I get a better understanding of the world outside of school.	1	2	3	4	5
29.	I learn interesting things about the world outside of school.	1	2	3	4	5
30.	What I learn has nothing to do with my out-of-school life.	1	2	3	4	5
	CRITICAL VOICE	**Almost Never**	**Seldom**	**Some-times**	**Often**	**Almost Always**
31.	It's OK for me to ask the teacher "Why do I have to learn this?"	1	2	3	4	5
32.	It's OK for me to question the way I'm being taught.	1	2	3	4	5
33.	It's OK for me to complain about teaching activities that are confusing.	1	2	3	4	5
34.	It's OK for me to complain about anything that prevents me from learning.	1	2	3	4	5
35.	It's OK for me to express my opinion.	1	2	3	4	5
36.	It's OK for me to speak up for my rights.	1	2	3	4	5
	STUDENT NEGOTIATION	**Almost Never**	**Seldom**	**Some-times**	**Often**	**Almost Always**
37.	I get the chance to talk to other students.	1	2	3	4	5
38.	I talked to other students about how to solve problems.	1	2	3	4	5
39.	I explain my understanding to other students.	1	2	3	4	5
40.	I ask other students to explain their thoughts.	1	2	3	4	5
41.	Other students ask me to explain my ideas.	1	2	3	4	5
42	Other students explain their ideas to me.	1	2	3	4	5

In this questionnaire contained in Appendix A, Items 1–24 are from the What Is Happening In this Class? (WIHIC) developed by Fraser, McRobbie and Fisher (1996), Items 25–42 are from a modified version of the Constructivist Learning Survey (CLES) (Aldridge et al., 2000; Taylor et al., 1997). All the items and scales were used in my study and included in this thesis with their authors' permission.

Appendix B

Test of Science Related Attitudes (TOSRA)

	ATTITUDE OF SCIENTIFIC INQUIRY	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
1.	I would prefer to find out why something happens by doing an experiment than by being told.	1	2	3	4	5
2.	Doing experiments is not as good as finding out information from teachers.	1	2	3	4	5
3.	I would prefer to do experiments than to read about them.	1	2	3	4	5
4.	I would rather agree with other people than do an experiment to find out for myself.	1	2	3	4	5
5.	I would prefer to do my own experiments than to find out information from a teacher.	1	2	3	4	5
6.	I would rather find out things by asking an expert than by doing an experiment.	1	2	3	4	5
7.	I would rather solve a problem by doing an experiment than by being told.	1	2	3	4	5
8.	It is better to ask the teacher the answer than to find out by doing an experiment.	1	2	3	4	5
9.	I would prefer to do an experiment on a topic than to read about it in science magazines.	1	2	3	4	5
10.	It is better to be told scientific facts than to find them out from experiments.	1	2	3	4	5

	ENJOYMENT OF SCIENCE LESSONS	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
11.	Science lessons are fun.	1	2	3	4	5
12.	I dislike science lessons.	1	2	3	4	5
13.	Schools should have more science lessons each week.	1	2	3	4	5
14.	Science lessons bore me	1	2	3	4	5
15.	Science is one of the most interesting school subjects.	1	2	3	4	5
16.	Science lessons are a waste of time.	1	2	3	4	5
17.	I really enjoy going to science lessons.	1	2	3	4	5
18.	The material covered in science lessons is uninteresting.	1	2	3	4	5
19.	I look forward to science lessons.	1	2	3	4	5
20.	I would enjoy school more if there were no science lessons.	1	2	3	4	5

	SOCIAL IMPLICATIONS OF SCIENCE	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
21.	Money spent on science is well worth spending.	1	2	3	4	5
22.	Science is a person's worst enemy.	1	2	3	4	5

23.	Public money spent on science in the last few years has been used wisely.	1	2	3	4	5
24.	Scientific discoveries are doing more harm than good.	1	2	3	4	5
25.	The government should spend more money on scientific research.	1	2	3	4	5
26.	Too many laboratories are being built at the expense of the rest of education.	1	2	3	4	5
27.	Science helps to make life better.	1	2	3	4	5
28.	This country is spending too much money on science.	1	2	3	4	5
29.	Science can help to make the world a better place in the future.	1	2	3	4	5
30.	Money used on scientific projects is wasted.					

Scoring: Omitted or invalid responses are scored a 3. To obtain the total score for each scale, add the scores for eight items in each scale (maximum is 40). To calculate the "mean item score" divide the total score for each scale and divide.

In the questionnaire contained in Appendix B, items 1–30 are based on modified version of the Test Of Science-Related Attitudes (TOSRA) developed by Fraser (1981). All the items and scales were used in my study and included in this thesis with their authors' permission.

Appendix C

Human Research Ethics Committee: Protocol Approval

memorandum

Curtin
University of Technology

To	Obiorah Ebo, SMEC
From	Pauline Howat, Coordinator for Human Research Ethics, Science and Maths Education Centre
Subject	Protocol Approval **SMEC20080057**
Date	27 October 2008
Copy	Barry Fraser, SMEC Divisional Graduate Studies Officer, Division of Science and Engineering

Office of Research and Development

Human Research Ethics Committee

TELEPHONE 9266 2784
FACSIMILE 9266 3793
EMAIL hrec@curtin.edu.au

Thank you for your "Form C Application for Approval of Research with Minimal Risk (Ethical Requirements)" for the project titled "*EVALUATION OF INQUIRY-BASED LEARNING IN GRADE 5–6 EARTH SCIENCE: LEARNING ENVIRONMENT, ATTITUDES AND ACHIEVEMENT*". On behalf of the Human Research Ethics Committee I am authorised to inform you that the project is approved.

Approval of this project is for a period of twelve months **27th October 2008** to **26th October 2009**.

If at any time during the twelve months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately. The approval number for your project is **SMEC20080057**. *Please quote this number in any future correspondence.*

Pauline

PAULINE HOWAT
Coordinator for Human Research Ethics
Science and Maths Education Centre

Please Note: The following standard statement must be included in the information sheet to participants: *This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number SMEC20080057). If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784.*

Appendix D

Letter of Permission to the Superintendent of Schools

SCIENCE AND MATHEMATICS EDUCATION CENTRE

Letter of Permission to the Superintendent of Schools

To: Mr/Ms/Dr/XXXXXXXXXXXXX Date: September 10, 2008

The Superintendent of Schools,

XXXXXXXXX Unified School District

From: Obiorah Ebo,

Science Teacher Cabrillo High School Long Beach, Primary Investigator

Professor Barry Fraser, Supervisor and Co- Investigator,

Curtin University of Technology, Perth Western Australia

Dear Superintendent,

Request for Permission to Conduct Research at Your School Sites

I wish to request for a written permission to conduct a doctoral dissertation research with the high school students in your school district. The topic for my research is: *Evaluation of Inquiry-Based Learning in High School Science Classrooms: Learning Environment and Attitudes.* The study will assess students' perceptions of inquiry-based science classroom environments in terms of their attitudes to science learning. It will utilize intact classrooms and will not disrupt school's curricular goals and teachers' instructional assignments. I therefore solicit for your permission to enable students and teachers participate in this research.

The results of the study will be communicated to the district as it might help provide insight on the effectiveness of inquiry-based practices in science classrooms environments. The study will also evaluate teachers' preparedness for the implementation of the Common Core and New Generation Science Standards. Data from this study may be used by teachers, school administrators, and curriculum planners to develop and modify science curriculum to improve science instruction.

Participation is strictly voluntary and will involve students' participation in completing a 72-question survey. To participate in this study, parents will be required to sign a consent letter permitting their children to participate in the survey. This letter will contain, among other things, information describing the purpose of the study, students' statutory rights, privacy and confidential statements, as well as time and duration of the research. A copy of the participants' letter of consent is attached here-in for your perusal.

This investigation will strictly adhere to all procedures including protecting participants and teachers' statutory rights, privacy and confidentiality as well as ethics governing the use of human research. Students' private information will not be required in this survey.Rather, all names will be coded using pseudonyms and surveys will be identified numerically. During and after this investigation, only the researcher and co-researcher will have access to the survey data.

For questions or further information, please contact the researcher; Obiorah Ebo at OOEbo@lbschools.net or co-research; Dr. Barry Fraser at BFraser@curtin.edu.au.

Thanks for your kind consideration and continued assistance towards this research.

Yours Sincerely,

____________________	______________________	_______________
Superintendent	*Signature*	*Date*

Appendix E

Letter of Permission to the School Principal

SCIENCE AND MATHEMATICS EDUCATION CENTRE

Letter of Permission to the School Principal

To: Principal, Date: December 05, 2008

Attention: XXXXXXXXXXXXX

XXXXXX High School

From: Obiorah Ebo,

Science Teacher Cabrillo High School Long Beach, Primary Investigator,

Professor Barry Fraser, Supervisor and Co-Investigator,

Curtin University, Perth Australia

Dear Principal;

Request for Permission to Conduct Research at Your School Site

I am a science teacher at XXXXXXXXXXX and currently conducting an academic research in Science Education (emphasis on Classroom Environment) and therefore wish to request for your approval to conduct an academic research for doctoral dissertation at your school site. The topic for my research is: ***Evaluation of Inquiry-Based Learning in High School Science Classrooms: Learning Environment and Attitudes.*** The study will require grades 9–12 science students to complete questionnaires. The primary focus of the study is on evaluating students' perceptions of inquiry-based learning in science classrooms in terms of their attitudes to science learning. Your permission will enable the students and teachers participate in this research. Approval has already been granted with a letter signed by the District's Director of Research and Evaluation. A copy of the signed letter is herein attached.

This study is not aimed at observing and evaluating teaching performances of teachers, but to assess the attitudes and perceptions of students in classrooms where inquiry-based practices are used and will in no way obstruct or disrupt district's and school's curricular goals and teachers' instructional assignments.Students' and teachers' participation in this study is strictly voluntary and participants could withdraw anytime they choose to. To participate in this research, letter of consent signed by parents must be returned to the research before the administration of the questionnaire. The consent letter contains, among other things, the purpose of the study, students' rights to privacy and confidentiality, and time and duration for the completion of the questionnaire. A copy of the participants' letter of consent is attached here-in.

For questions and concerns, you may wish to contact me at 562-412-XXXX email ebeobi1@aol.com. You may also contact my research supervisor and co-researcher, Dr. Barry Fraser at 1-618-9266-XXXX or contact by email at B.Fraser@curtin.edu.au.

Thanks for your kind cooperation and continued support to the success of this project.

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Yours Sincerely,
Obiorah Ebo

______________________	____________________	________________
Name of Principal or Designee	Principal's Signature	Date

Name of School: ____________________________ District: _____________________

Appendix F

PARENTS' INFORMATION SHEET

SCIENCE AND MATHEMATICS EDUCATION CENTRE

PARENTS' INFORMATION SHEET

Evaluation of Inquiry-based learning in High-School Science Classrooms: Learning Environment and Attitudes.

My name is Obiorah Ebo, a doctorate research student at Curtin University of Technology, Perth, Western Australia and the primary investigator. My supervisor/ co-researcher isDr Barry Fraser, Director of Science and Mathematics Education Centre of the University. Your child has been being asked to participate in a research study that is designed to evaluate students' attitudes and perceptions of inquiry-based learning in science classroom. This consent form provides details information about the research Please carefully read the information contained in this document. Examples of the type of questions your child would be asked are contained in this document. The research objectives, student's responsibilities, and statutory rights, protection, privacy and confidentiality are contained in this document.

Purpose of the Study

The purpose of this study is to examine and evaluate the impact of inquiry based learning environment in science classrooms. The study will focus on analysing how students perceive their classrooms and how such perceptions modify their attitudes towards science learning. The investigation will not require your child to do anything beyond what he/she was already doing in the science classroom. The results and final document from this study will be presented to the school district and this provide information that will assist science teachers and school administration in providing the best instruction for students in science education

Your Child's Role

During this investigation, your child will be asked to complete a 72-question survey titled Inquiry-Based Learning Environment Survey IBLES). Instruction in completing the survey is contained in the survey packet. Completing the survey will take about 10 to 15 minutes. This survey is short and simple and will be given to your child by his or her teacher. Your child will be expected to provide simple and honest answers about their perceptions of their science classroom. Participation in this study is voluntary and your child can withdraw from participation any time he/she chooses to do so. The study involves no foreseeable risks or harm to your child.

Privacy and Confidentiality

All statutory guidelines and regulations pertaining to privacy and confidentiality will be strictly followed. As a result, your child's name, school's or state identity number will not be used during the process of this investigation. Completed questionnaires will be marked using pseudonyms numerical code to maintain anonymity and confidentiality. There is no physical, emotional or psychological risk associated with this study. At the end of this research, all completed questionnaire data will be securely kept in a locked compartment with Curtin University for five years and after then, it will be destroyed.

Consent to Participate

Your child's participation in this survey will not disrupt his/her learning time in the classroom. Also, it will not affect your child's academic grade nor provide any form of privilege or special consideration to your child.

Before you give your consent to volunteer, it is important that you read the following information and ask as many questions as necessary to be sure that you understand what you will be asked to do. Enter your initial after the statement below to acknowledge your understanding of the statement. When you are satisfied with the procedures and requirements, check the box below to indicate that you permit your child to participate in the survey. By signing this form, you consent to permit your child to participate in this survey.

Approvals to Conduct the Research

This research proposal has been thoroughly reviewed and approval granted by Curtin University of Technology Human Research Ethics Committee. Also, written approval has been granted by the school district signed by the superintendent of schools, by the school principal, and by your child's science teacher. If you require further information about this study or would like to speak to the researcher, please call 562-XXX-XXXX or by email contact at ebeobi1@aol.com. You may also contact my research supervisor, Dr. Barry Fraser at 1-618-XXXX-XXXX or by email at B.Fraser@curtin.edu.au.

Below are a few samples questions your child will be asked in the questionnaire:

- Science lessons are fun.
- I dislike science lessons.
- Schools should have more science lessons each week.
- Science lessons bore me
- Science is one of the most interesting school subjects.

Appendix G

PARENTS' LETTER OF CONSENT

Curtin University of Technology

SCIENCE AND MATHEMATICS EDUCATION CENTRE

PARENTS' LETTER OF CONSENT

To give consent for your child to participate, please kindly indicate your willingness to participate. Carefully review your rights listed at the bottom of this page and enter your initials on each to acknowledge that you understood each statements, then sign and date. Return signed copy to your child's teacher.

- I have read and understood the purpose and procedures for this research.
- I understand that my child's participation in this surveydoes not guarantee any form of benefits, special rights and privileges.
- I understand that participation in this survey is strictly voluntary and I have the rights to withdraw my child from participating at any time without penalty
- I understand that there is no foreseeable risk associated with your child's involvement in this survey
- I have been provided with opportunity to ask questions and clarify ideas about this research
- I understand that my responses to the survey questions will be used to complete the writing doctoral dissertation

I have read this informed letter of consent and voluntarily give the consent for my child to participate in this study.

____________________ *Name of Students* ____________________ *Name of Parent*

____________________ *Signature of Parent* ____________________ *Date*

Appendix H

TEACHERS’ INFORMATION SHEET

SCIENCE AND MATHEMATICS EDUCATION CENTRE

TEACHERS' INFORMATION SHEET

My name is Obiorah Ebo, a doctorate research student at Curtin University of Technology, Perth, Western Australia and my supervisor is Dr Barry Fraser, Director, Science and Mathematics Education Centre and Dean, Graduate Studies; Science and Engineering. This document provides details information about things you might want to know regarding this study such as: your roles, guidelines, privacy and confidentiality as well as ethics and statutory rights of the students. .

The purpose of this study is to examine and evaluate the impact of inquiry based learning environment in high-school science classrooms. Emphasis will centre on analysing how students perceive their classrooms and how such perceptions modify their attitudes towards science learning. The investigation will not require you to change or modify your instruction, but continue to follow your daily instructional plans. The results of the study will be communicated to you through the district office.

During this investigation, your role is to administer the 72-question survey titled Inquiry-Based Learning Environment Survey IBLES). Also to facilitate, collate and collect all completed questionnaires at the end of the testing. Details of the test administration guidelines are attached to this document. The questionnaire will take approximately 10 to 15 minutes to complete. Participation in this study is voluntary and you can withdraw from participation any time you wish to do so. Students' privacy and confidentiality will be maintained, Personal names and identification numbers will not be used on the forms, rather questionnaires will be identified using numerical code. There is no physical, emotional or psychological risk associated with this study. At the end of this research, all completed questionnaire data will be securely kept in a locked compartment with Curtin University for five years and after then, it will be destroyed.

This research proposal has been thoroughly reviewed and approval granted by Curtin University of Technology Human Research Ethics Committee. Also, written approval has been granted by the school district signed by the superintendent of schools, and also by the school principal.

If you have further questions or concerns, I may be contacted atOOEbo@lbschools.net. You may also wish to contact my research supervisor, Dr. Barry Fraser at B.Fraser@curtin.edu.au.

Please return signed letters of consent to the researcher.

Thanks for your kind support and assistance

Appendix I

TEACHERS' LETTER OF CONSENT

Curtin University of Technology

SCIENCE AND MATHEMATICS EDUCATION CENTRE

TEACHERS' LETTER OF CONSENT

Dear Teacher,

As you are aware, inquiry-based learning has become the central focus of the state science education program and is presently the foundation for the New Generation Science Standards. To this effect, I am conducting an investigation to evaluate students' perceptions and attitudes of inquiry-based learning environment in science classrooms. Therefore, on behalf of myself and my supervisor, I wish to express my appreciation for your willingness and desire to assist in collecting data for this research project. Attached with this letter are the following:

- Teacher's information sheet,
- Inquiry-Based Learning Environment Survey (IBLES) with the test administration guidelines,
- Principal's Letter of Approval,
- Parents Information Sheet and Letter of Consent.

All information collected from this study will be kept confidential and well secured. Below are the guidelines for administering the questionnaire:

- Inform parents that the surveys need to be completed in class and will take about 15 minutes to complete.
- Inform students and parents that the survey will be kept confidential and private and that they should not write their names on the questionnaire.
- Inform students to complete the demographic section before answering the questions.
- Inform students to answer all the questions and give their best honest answer.

- Students could use pen or pencil to circle their responses, and neatly cross out any answer choice they choose to change.
- Designate a student aide to assist non-English speaking students in completing the form
- Collate and collect all questionnaires including unanswered copies and seal in the envelope provided. Write the subject, class/period, room number, name of school, date and time of the assessment on the back of the envelope.
- For questions or concerns, you may reach me at 562-XXX-XXXX or by email at ebeobi1@aol.com.

Thanks again for your invaluable assistance and looking forward to working with you in the future.

Sincerely,

Obiorah Ebo

Teacher's Signature	Teacher's Name	Date