Science and Mathematics Education Centre

Associations Between Learning Environment and Students' Attitudes and Understanding of Nature of Science

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DECLARATION

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

Signature:

Date: May 2016

DEDICATION

To the memory of my sister Geeta Raja who believed in the goodness of everybody.

To the memory of my mother PC Ratnam Raja who always believed in me.

To the memory of my father KG Varma Raja who believed education was the path to everything.

ACKNOWLEDGEMENTS

You can't cross the sea by merely standing and staring at the water.

Rabindranath Tagore (1861-1941)

As I often stared at the water, I am eternally indebted to Dr. Barry Fraser for his wisdom, guidance, and infinite patience. Through him, I have been introduced to people and ideas I would never had encountered. He is a historian, expert, advocate, and keeper of more knowledge than can be imagined. His expertise and knowledge in the field of Learning Environments is unmatched.

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ABSTRACT

The purpose of the study was the validation of questionnaires assessing classroom learning environments – What Is Happening In this Class? (WIHIC), attitudes to science – Test of Science Related Attitudes (TOSRA), and understanding of the nature of science (NOS) – Scientific Attitude Inventory: Revised (SAI-II) and Views On Science and Education (VOSE) among urban secondary school students; and the investigation of characteristics of the science classroom learning environment that are related to students' attitudes to science and understanding of NOS.

Modified versions of existing instruments were used to assess the learning environment (WIHIC); student attitudes (TOSRA); and understanding of NOS (SAI-II and VOSE). To avoid confusing students and to maintain consistency, the same Likert response scale (Strongly Agree, Agree, Not sure, Disagree, and Strongly Disagree) was used for all scales and items. The modified questionnaires were administered to a sample of 246 students in a Midwestern United States secondary school with urban demographics. Factor analysis on the data with varimax rotation and Kaiser normalization was performed on the data and were used for determining factor loadings for: the 32 WIHIC learning environment items; the 12 TOSRA attitude items; and the 18 SAI-II/VOSE NOS items. The two criteria for the retention of any item was that it must have a factor loading of at least 0.40 with its own scale and less than 0.40 with all other scales.

After slight modifications, the 31 learning environment items accounted for 52.12% of the variance of the WIHIC scales, and the 11 NOS items accounted for 45.78% of the variance of the SAI-II/VOSE scales. The 12 attitude items accounted for 51.33%

of the TOSRA scales. With the individual student as the unit of analysis, environment scales were statistically significantly correlated ($p<0.01$) with each attitude scale (Social Implications and Normality) and with each NOS scale (Tentative Nature and Scientific Method).

Investigation and Task Orientation were statistically independent predictors for student attitudes to the Social Implications of Science. Task Orientation was a statistically significant independent predictor for Normality of Scientists. Investigation, Cooperation and Task Orientation were statistically significant independent predictors for Tentative Nature of Science. Investigation and Task Orientation was statistically significant independent predictors for Scientific Method.

The study replicated prior research on associations between the learning environment and student attitudes towards science at the secondary level. Consistent with past research, all bivariate and multivariate associations were positive. Overall, the results of the study suggest the existence of statistically significant associations between students' learning environment and their attitude to science and understanding of NOS. These results suggest that greater emphasis on the classroom learning environment dimensions investigated in my study – Involvement, Investigation, Cooperation, and Task Orientation – is linked with improving student attitudes toward science and understanding of NOS.

To confirm the findings of the study and to reduce the limitations associated with the study, additional studies could involve more diverse samples, include qualitative information, and include other educational constructs.

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INTRODUCTION

1.1 Context of the study

As educators, we complain about the inability and/or lack of desire among many of our students to think for themselves. Many students cannot evaluate data, analyze data, or draw conclusions without specific instructions and often students want to be told the 'right' answer without concern for the process because they are unaccustomed to being asked to evaluate their own or others responses. This is of particular concern when their conceptions are contrary to accepted scientific knowledge; telling the right answer will not change their belief in the wrong answer. Unfortunately, many students believe science is an unchanging collection of facts. They believe what an authority figure (e.g. the television, radio, or newspaper) tells them. There is a strong need for students to evaluate the legitimacy of a scientific claim; to understand the ethics of controversial issues (stem cell research, global warming, weapons of mass destruction, etc.); and to be informed decision makers (Belardo, 2001; Rutherford & Ahlgren, 1990). Part of the reason they cannot do these things is that students have not been taught how.

Too often science is taught as a set of procedures and facts, and it is not seen as a process that builds and grows. The goal, then, is to teach students how to *do* science. To teach *doing*, teachers must model the ways of doing science and allow students opportunities to also do, discuss, and communicate about science. These opportunities help to form students' understanding of nature of science and fall into two broad categories – explicit and implicit instruction. The explicit curriculum comes from textbooks, procedural laboratory experiences, and explanations by the teacher. The implicit curriculum comes from the language used by the teacher, the intellectual freedoms allowed to students and laboratory experiences (both procedural and open-ended). This implicit curriculum can be inferred from the classroom learning environment.

Research has shown that teachers typically view the learning environment in their own classroom more positively than the students do (Fraser, 1998a, 2002, 2012). It is often difficult to separate what is thought to be taught (content) or modeled (attitudes) from what is learned. The literature also shows that the learning environment not only affects student achievement, but that it also influences the affective domains of attitude and interest (Fraser, 2012).

How the learning environment in a science classroom affects student achievement has been studied frequently (Fraser, 2012). But the value of the affective domain must also be recognized. In other words, there is a value in how students feel and think about science. There have been numerous studies of the relationship between learning environments, achievement, and affective outcomes (Aldridge, Dorman, & Fraser, 2004; H. B. Kim, Fisher, & Fraser, 1999, 2000; Koul & Fisher, 2005; Turkmen & Bonnstetter, 1999; Waxman & Huang, 1997). Meyers and Fouts argue “that attitude toward school subjects is itself an important and desirable educational outcome.” (1992, p. 929). Positive attitudes toward science and science learning are necessary to engage students in learning (Bruce, Bruce, Conrad, & Huang, 1997). In addition, students with a positive attitude toward a subject tend to want to learn more about it, both positive and negative attitudes can be shared with others even after leaving school (Myers & Fouts, 1992).

In my study, I investigated associations between the learning environment as perceived by students and their attitudes toward science and understanding of nature of science. In addition, I provided validity for an instrument used to investigate students' understanding of nature of science. To these ends, I decided to use the What Is Happening In this Class (WIHIC), Test Of Science Related Attitudes (TOSRA), Scientific Attitude Inventory: Revision (SAI-II) and Views on Science and Education Questionnaire (VOSE) to investigate the associations between perceptions of the classroom learning environment, attitudes, and understanding of nature of science.

This chapter provides a context for my study by briefly considering a theoretical framework for learning environments, attitudes towards science, and understanding nature of science; the research questions; and the significance of my study. The chapter includes the following sections:

- Theoretical Framework (1.2)
- Research Questions (1.3)
- Significance (1.4)
- Overview of the Thesis (1.5).

1.2 Theoretical Framework

This section provides brief background information regarding the fields of leaning environments (Section 1.2.1), attitudes towards science (Section 1.2.2), and understanding nature of science (Section 1.2.3). A more-comprehensive review of literature in each of these three areas is provided in Chapter 2.

1.2.1 Learning Environment

Early learning environments research was motivated by the ideas of Lewin (1936a) and Murray (1938) who recognized a relationship between a person and his or her environment. Lewin (1936a) described an individual's behavior (B) as a function (f) of personal characteristics (P) and the environment (E): B=f(P, E). The individual's personal characteristics are a combination of many factors (Lewin, 1943). The environment of the educational setting and is dependent on realizing that "education is in itself a social process" (1936b, p. 266) and leads to behaviors and attitudes in both students and teachers. Following Lewin's approach of behavior, Murray (1938) proposed a need–press model, in which needs are an individual's personal requirements and the desire to achieve them, and press consists of influences on the individual. He characterizes internal self-reported influences as 'beta press' and external observable influences as 'alpha press' (Murray, 1938).

In the 1960s and 1970s, the pioneering work by Moos (1974) and Walberg (Walberg & Anderson, 1968) led to research on classroom learning environments. Walberg's work identified the learning environment as one of nine factors that affect educational productivity (Reynolds & Walberg, 1991). Walberg (1980) proposed that educational productivity is a function of nine factors, is multiplicative and has diminishing returns. These factors can be grouped into properties of the individual (student ability, cognitive development, and student motivation), the instruction (quality of instruction and quantity of instruction), and the environment (the psychosocial classroom environment, educationally stimulating conditions in the home and among peer groups, and exposure to mass media).

Moos began developing the first of his social climate scales, the Ward Atmosphere Scale, for use in psychiatric hospitals to assess the social climate of hospital-based ward treatment environments (Moos, 1973). He found that individual aspects of all human environments could be described by three dimensions: Relationship, Personal Development, and System Maintenance and System Change. Moos' work in nine human environments (Moos, 1974) eventually led to the development of the Classroom Environment Scale (CES) (Moos & Trickett, 1974).

Unlike Moos, Walberg began his research in an educational environment. Prior to developing the Learning Environment Inventory (LEI), Walberg (1968) created the Classroom Climate Questionnaire (CCQ) based on the work of Hemphill and Westie (1950). When the CCQ was found to have several weak scales, it was modified to form the LEI (Walberg & Anderson, 1968) and used in evaluating the effectiveness of a new curriculum (Harvard Project Physics) for high-school students.

1.2.2 Science Attitudes

Students' attitudes towards studying science have received much attention in science education for over 40 years (Tytler & Osborne, 2012), partly because of declining interest in school science and a disinterest in science careers (Blalock et al., 2008). According to Gardner (1975, 1995), 'attitudes towards science' involve how individuals *feel* about science. These *attitudes* are variables such as relevance, value, and enjoyment, whereas 'scientific attitudes' refer to qualities that an individual has that are generally considered desirable in a good scientist. These *attitudes* are variables such as empiricism, skepticism, and determinism.

Klopfer (1976) helped to resolve the semantic confusion with the term 'attitude' by delineating six conceptually-distinct categories of science attitudes. The problem of meaning is further compounded by the understanding that attitude toward science is a multifaceted concept (Tytler & Osborne, 2012) that includes overlapping concepts of: attitudes towards science and scientists; attitudes towards school science; enjoyment of science learning; interest in science and science-related activities; and interest in pursuing a career in science. A review of the literature regarding science attitudes is given in Chapter 2, Section 2.6.

1.2.3 Nature of Science (NOS)

For many decades, science education and educators have identified the need for students to develop an understanding of nature of science (Heiss, 1958), but this does not usually appear as a topic in science course syllabi (Martin-Dunlop & Hodum, 2009). An important issue to clarify is the meaning of 'nature of science' and its meaning in different disciplines. Alters (1997) identified 39 tenets of NOS in the science education literature, including characteristics that have reached consensus (Giddings, 1982), such as that science is observation oriented (Cleminson, 1990), a human endeavor (Aikenhead & Ryan, 1992), and dependent on culture (AAAS, 1993). In addition, different scientists (i.e., biologists, chemists, and physicists) could view statements differently, with additional differences between scientists, science educators, and science philosophers (Doran, Guerin, & Cavalieri, 1974). In spite of these differences, researchers have developed instruments to investigate understanding of NOS.

An instrument for assessing students' understanding of NOS should have four characteristics: be based upon specification of the particular attitude to be assessed; use several items to assess each attitude; allow the respondent to indicate the extent of his acceptance or rejection of an attitude statement; and be concerned with intellectual and emotional scientific attitudes. A more-thorough review of the literature regarding NOS is given in Chapter 2, Section 2.7.

1.3 Research Questions

The goal of my study was to investigate associations between the classroom learning environment and the student outcomes of attitudes toward science and understanding nature of science. My two research questions were:

Research Question 1

Are learning environment scales based on the WIHIC, attitudes scales based on the TOSRA, and nature of science scales based on the SAI-II and VOSE valid when used with students in a suburban secondary school with urban demographics in mid-western USA?

Research Question 2

What are the characteristics of the science classroom environment that enhance students' attitudes to science and understanding of nature of science?

1.4 Significance

My study is substantively significant because it included the three fields of classroom learning environments, students' attitudes toward science, and students' understanding of nature of science; these three areas have not often been studied together. If one of the primary goals of science education is to ensure that students become scientifically literate members of society, what does a science classroom that develops scientifically-literate students look like?

A methodological contribution of this study is that it led to the development and validation of economical and widely-applicable scales for assessing classroom environment and students' attitudes to science and understanding of the nature of science.

The research is practically significant because it identified associations between what students perceive is happening in the classroom environment and their attitudes towards science and their understanding of nature of science. This research evidence tentatively provides guidance to teachers about what emphases in their classroom environments are likely to promote student attitudes and understanding of NOS.

1.5 Overview of the Thesis

Chapter 1 introduced the context of my study and provided brief background information about learning environment, science attitudes, and nature of science. It also identified my two research questions and the significance of the study.

A review of relevant literature is presented in Chapter 2. The review includes historical background in learning environments, instruments for assessing learning environments, and past research on learning environments. Specific attention is given to the WIHIC in Section 2.4 because it was chosen for assessing classroom environment in my study. Similarly, instruments and past research are reviewed for attitudes towards science and understanding of nature of science, with particular attention to the questionnaires used in my study.

In Chapter 3, the development of the questionnaire, sample, procedures for collecting data, and procedures for analyzing the data are described. The modifications made to existing instruments when combined into one instrument are described.

The results of the data analyses are reported in Chapter 4 in order to answer my research questions. The validity and reliability of the modified questionnaire are reported. In addition, associations between the classroom learning environment and the student outcomes of attitudes toward science and understanding nature of science are identified.

Chapter 5 concludes the thesis by summarizing the whole thesis and further discussing its results. As well, the study's limitations are identified and some desirable future research directions are suggested. Substantive, methodological and practical implications of my research are delineated.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

Whereas the previous chapter introduced a context for this study, this chapter provides a review of the literature on topics related to my study. Because the main constructs investigated in my study were the learning environment, student attitudes to science, and student understanding of the nature of science, literature on these areas is reviewed in this chapter using the following headings:

- Historical Background of Learning Environments (2.2)
- Instruments for Assessing Learning Environments (2.3)
- What Is Happening In this Class? (2.4)
- Research Involving Classroom Environment Instruments (2.5)
- Assessment of Attitudes towards Science (2.6)
- Assessment of Understanding of Nature of Science (2.7)
- Chapter Summary (2.8).

The literature on learning environments is extensive. In 1998, Fraser completed a thorough review of learning environments literature spanning the previous four decades, namely, the 1960s to the 1990s (1998b). He has visited the literature again recently to document the growth and development in the field (Fraser, 2012). In particular, there have been numerous studies of the relationship between learning environment, achievement, and affective outcomes conducted at the regional (Waxman & Huang, 1997), national (H. B. Kim et al., 2000; Koul & Fisher, 2005;

Turkmen & Bonnstetter, 1999), and cross–national levels (Aldridge & Fraser, 2000; Dorman & Ferguson, 2004; Fraser, Aldridge, & Adolphe, 2010).

2.2 Historical Background of Learning Environments

Historically, classroom environments have been studied in a quantitative way based on participants' perceptions, but recent approaches in educational research include interpretative methods (Fraser & Tobin, 1991; Tobin & Fraser, 1998). Two fundamental beliefs underpin the perceptual approach. The first is that students, as members of the classroom, are in a position to provide insights that an outside observer might not have. Secondly, these students are capable of conveying those insights (Fraser, 1998a). With the acceptance of these beliefs comes the ability to learn about what is happening in classrooms by asking the students. Past research has shown that, even within the same environment, there can be differences in these insights based on student gender, ethnicity, and ability (Fraser, 1998a, 1998b, 2002).

Early learning environments research was motivated by the ideas of Lewin (1936a) and Murray (1938). Both of these researchers recognized the existence of a relationship between a person and his or her environment. School environment instruments were developed as early as 1958, but they were awkward and did not have a clear theoretical basis (Fisher & Fraser, 1990). In the 1960s and 1970s, the pioneering work by Moos (1974) and Walberg (Walberg & Anderson, 1968) led to research on classroom learning environments. While Moos' original work was not about educational settings, it was easily adaptable (Fisher & Fraser, 1990).

Walberg's work identified the learning environment as one of nine factors that affect educational productivity (Reynolds & Walberg, 1991).

Lewin (1936a) describes an individual's behavior (*B*) as a function (f) of the individual's personal characteristics (*P*) and the environment (*E*): $B=f(P, E)$. The individual's personal characteristics are a combination of many factors and depend on what is happening 'at that time' (Lewin, 1943). Personal characteristics include physical aspects such as gender, race, and age (Van Petegem, Aelterman, Van Keer, & Rosseel, 2008), educational aspects such as "cognitive complexity and interpersonal maturity" (Hunt, 1975, p. 217), and the individual's traits, values, and modes of function (Mitchell, 1969). The second variable is the environment of the educational setting, which recognizes that "education is in itself a social process" (Lewin, 1936b, p. 266) and develops behaviors and attitudes in both students and teachers. Factors that influence an educational setting are the sociological properties of that group, both expressed and tacit. The environment is also influenced by the larger social group of which the educational setting is a part. The general atmosphere of this larger group, therefore, affects the smaller educational group (Lewin, 1936b).

Following Lewin's approach, Murray (1938) proposed a need–press model, in which needs are an individual's personal requirements and the desire to achieve them, and press consists of influences on the individual. He characterizes the internal self-reported influences as beta press and the external observable influences as alpha press (Murray, 1938). Beta press has been further differentiated as either private (as viewed by the individual) or consensual (as viewed by the group) (Stern, Stein, & Bloom, 1956). Private and consensual press involve different units of analysis, the individual and the group, respectively.

Bandura (1978) further extended the conceptualization of the relationship between behavior, personal characteristics, and the environment. Not only do the individual and the environment influence behavior, but behavior influences the individual and the environment. All three influence each other with the process being iterative.

In the early 1960s, Moos and Walberg, independently, were studying psychiatric and learning environments, respectively. Moos began developing the first of his social climate scales, the Ward Atmosphere Scale, for use in psychiatric hospitals for assessing the social climate of hospital-based ward treatment environments (Moos, 1973). Patients and staff were asked individually about the usual patterns of behavior in their program. Moos (1974) asserted that human behavior is shaped and directed by the environment as perceived subjectively by the people in it and that patients and staff members often perceive the same environment somewhat differently. He found that individual aspects of human environments could be described by three dimensions: Relationship, Personal Development, and System Maintenance and System Change.

The Relationship dimension assesses how well someone supports and is supported in his/her environment. The Personal Development dimension assesses how well someone improves in the environment. The System Maintenance and System Change dimension assesses how much order, organization, clarity, and control there is in the environment (1973). These dimensions characterize the nine types of social environments studied by Moos and his associates – psychiatric wards, community-oriented psychiatric programs, correctional facilities, military basic training companies, university residences, junior and senior high school classrooms, social task-oriented therapeutic groups, work environments, and families (1973). Based on Moos' theoretical perspectives, a number of questionnaires have been developed for assessing classroom learning environments.

Unlike Moos, Walberg began his research in educational settings. Prior to developing the Learning Environment Inventory (LEI), Walberg (1968) created the Classroom Climate Questionnaire (CCQ) based on the work of Hemphill and Westie (1950). The CCQ was found to have several weak scales, and two-thirds of the scales only had two or three items. In addition, the CCQ did not represent classroom interactions well and omitted some important dimensions (Fraser, Anderson, & Walberg, 1982). Because of these shortcomings and problems with the instrument, the CCQ was modified to create an early version of the LEI (Walberg & Anderson, 1968), which was revised in 1971 (Anderson, 1973) and again in 1982 (Fraser et al.).

The CCQ, and subsequently the LEI, was created in response to a need to measure the effectiveness of a new curriculum, Harvard Project Physics, for high school students. The method used in evaluating the curriculum was guided by three factors: monetary cost, the need for codeable information on interactions that was not related to student learning, and the belief that students were a more reliable source of information than outside observers (Fraser et al., 1982).

In addition to the LEI, Walberg has also contributed to classroom learning environments research through his theory of educational productivity. He proposed that educational productivity is a function of nine factors, is multiplicative and has diminishing returns (Walberg, 1980). These factors can be grouped into properties of the individual (student ability, cognitive development, and student motivation), the instruction (quality of instruction and quantity of instruction), and the environment (the psychosocial classroom environment, educationally stimulating conditions in the home and among peer groups, and exposure to mass media) (Reynolds & Walberg, 1991). Four of these factors (student ability and motivation, and instructional quality and quantity) are necessary and must be present at some minimum level for classroom learning to occur. In addition, the four environmental factors also correlate to classroom learning outcomes; however, their roles are less clear (Haertel, Walberg, & Weinstein, 1983).

Several factors seem important for improving educational productivity – instructional quality and time appear to have a significant effect on learning (Walberg, 1986). There is then the question of whether the four necessary factors can overcome the negative causal influences of the environmental factors. In fact, "instructional time appears to be a particularly important variable, in that it mediates motivation, class environment, peer environment, and mass media" (Reynolds & Walberg, 1991, p. 105). In addition, the effects of prior achievement could be tied to motivation and home environment, resulting in the last two factors having a more indirect effect.

2.3 Instruments for Assessing Learning Environment

There is a variety of research instruments available for assessing the learning environment in classroom settings. Not only have researchers employed several major questionnaires, but they have also modified these instruments to more suitably serve their own research purposes. The result is the availability of a growing set of valid and reliable instruments.

Table 2.1 provides an overview of 11 of these historically-significant and contemporary classroom learning environment questionnaires. For each questionnaire, this table shows the applicable educational level, the number of items contained in each scale, scale names, and the classification of each scale according to Moos' **(**1974**)** three types of dimensions (Relationship, Personal Development, and System Maintenance and Change). This table is based on Fraser (2012).

2.3.1 Learning Environments Inventory (LEI)

The LEI was initially developed and validated in the USA during late 1960s when Walberg evaluated and researched Harvard Project Physics (Walberg & Anderson, 1968) with senior high-school students. The questionnaire uses a four-point Likert scale to express agreement or disagreement with 105 questions evenly distributed across 15 scales. The scales can be classified using the three dimensions identified by Moos – Relationship (six scales), Personal Development (three scales), and System Maintenance and Change (six scales). There are some questions that are phrased negatively, and therefore are scored with reverse polarity. The LEI has been translated and validated into languages other than English, including Hindi (Walberg, Singh, & Rasher, 1977).

Table 2.1 Overview of Scales Contained in 11 Classroom Environment Instruments

			Scales Classified According to Moos' Scheme		
Instrument	Level	Items per Scale	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
Individualized Classroom Environment Questionnaire (ICEQ)	Secondary	10	Personalization Participation	Independence Investigation	Differentiation
College and University Classroom Environment Inventory (CUCEI)	Higher Education	7	Personalization Involvement Student Cohesiveness Satisfaction	Task Orientation	Innovation Individualization
My Class Inventory (MCI)	Elementary	6–9	Cohesiveness Friction Satisfaction	Difficulty Competitiveness	
Questionnaire on Teacher Interaction (QTI)	Secondary/ Primary	8–10	Leadership Helpful/Friendly Understanding Student Responsibility and Freedom Uncertain Dissatisfied Admonishing Strict		
Science Laboratory Environment Inventory (SLEI)	Upper Secondary/ Higher Education	7	Student Cohesiveness	Open-Endedness Integration	Rule Clarity Material Environment
Constructivist Learning Environment Survey (CLES)	Secondary	7	Personal Relevance Uncertainty	Critical Voice Shared Control	Student Negotiation
What Is Happening In this Class? (WIHIC)	Secondary	8	Student Cohesiveness Teacher Support Involvement	Investigation Task Orientation Cooperation	Equity
Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI)	Secondary	10	Student Cohesiveness Teacher Support Involvement Young Adult Ethos	Investigation Task Orientation Cooperation	Equity Differentiation Computer Usage

Constructivist-Oriented Learning Environment Survey (COLES)	Secondary	11	Student Cohesiveness Teacher Support Involvement Young Adult Ethos Personal Relevance	Task Orientation Cooperation	Equity Differentiation Formative Assessment Assessment Criteria

Based on Fraser (2012)

2.3.2 Classroom Environment Scale (CES)

The CES was also initially developed in the late 1960s. Unlike the LEI, the purview of the original research was not the school classroom, but rather a variety of human environments such as psychiatric hospitals, prisons, and work places (Moos, 1974). Like the LEI, the CES is also suited to the secondary-school level. The questionnaire uses a True/False response format for expressing agreement or disagreement with 90 questions that are evenly distributed across nine scales (Moos & Trickett, 1974; Trickett & Moos, 1973). The scales of the CES can also be classified using Moos' three dimensions – Relationship (three scales), Personal Development (two scales), and System Maintenance and Change (four scales). Approximately half of the questions are phrased negatively, and therefore are scored with reverse polarity. The CES has also been translated and validated into languages other than English, including Japanese (Hirata & Sako, 1998) and Indonesian (Paige, 1979). It has been cross-validated and successfully used in Australia (Fisher & Fraser, 1983).

2.3.3 Individualized Classroom Environment Questionnaire (ICEQ)

The ICEQ was developed for classrooms that are open-ended or inquiry-based in contrast to traditional settings (Fraser, 1990; Rentoul & Fraser, 1979). Like the LEI and CES, the ICEQ is aimed at secondary-school classrooms. The questionnaire uses a five-point frequency response scale to express the frequency of occurrence of events in the classroom (ranging from Almost Never to Almost Always). There are 50 items evenly distributed across five scales. The scales of the ICEQ can also be classified using Moos' three dimensions – Relationship (two scales), Personal Development (two scales), and System Maintenance and Change (one scale). Many of the questions are phrased negatively, and therefore are scored with reverse polarity. The ICEQ was developed for investigating the effect of the environment on student outcomes and differences between student and teacher perceptions, as well as for evaluating educational innovations or new curricula (Fraser & Fisher, 1986).

2.3.4 College and University Classroom Environment Inventory (CUCEI)

The CUCEI was developed for use in smaller university or other post-secondary classrooms (~30 students) (Fraser & Fisher, 1986). It contains 49 items evenly distributed across seven scales. The scales of the CUCEI can also be classified in terms of Moos' three dimensions – Relationship (four scales), Personal Development (one scale), and System Maintenance and Change (two scales). About half of the items have reverse polarity (Fraser & Treagust, 1986).

Fraser, Williamson, and Tobin (1987) used the CUCEI to assess students' perceptions of the classroom environment in two alternative high schools (senior colleges). Participating students completed an actual and a preferred form. The senior colleges were compared with three other control groups: students in two technical colleges offering evening interest classes, three Grade 11 and 12 classes in a conventional high school with adolescent and adult students, and three Grade 11 and 12 classes in a conventional high school with only adolescent students. Students in the alternative high school perceived their environment as having greater Involvement, Satisfaction, Innovation, and Individualization.

When the CUCEI was also used in first-year tertiary and Grade 12 and 13 secondary computing classrooms in New Zealand, some potential problems occurred with appropriateness, wording, length, and perceptions of repetitiveness between the actual and preferred versions (Logan, Crump, & Rennie, 2006). Negatively-worded questions caused some confusion and some students found that the time taken to complete each version was too long. An Arabic version of the CUCEI (Hasan & Fraser, 2015) was administered in the United Arab Emirates (UAE) to 84 males in college-level mathematics classes. The effectiveness of a mathematics program was investigated in terms of the nature of and changes in the learning environment and student satisfaction. Statistically significant pretest–posttest differences supported the effectiveness of using activity-based teaching strategies.

2.3.5 My Class Inventory (MCI)

The MCI is a simplified version of the LEI to be used with eight-to-ten year-old children, as well as with junior high school students who experience reading difficulties (Fraser et al., 1982). Simplification was accomplished by: reducing the number of items to minimize fatigue; modifying the wording to increase readability; reducing the four-point response format to a two-point (Yes–No) response format; and having students answer on the question sheet to avoid transfer errors. There are 38 items that are unevenly distributed across five scales (Fisher & Fraser, 1981), but a shorter 25-item version has been developed (Fraser & O'Brien, 1985). The scales of the MCI can be classified into two of Moos' three dimensions – Relationship (three scales) and Personal Development (two scales). One-fifth of the items have reverse polarity. A form of the MCI with a three-point response format (Seldom, Sometimes, and Most Times) has also been successfully used by Goh and Fraser (1998) in Singapore.

MCI was used in an evaluation of science kits (Houston, Fraser, & Ledbetter, 2008) among 588 Grades 3–5 students in three demographically-similar schools in Texas. One school used a textbook exclusively, one used science kits exclusively, and one used a combination of a textbook and science kits. For both Cohesiveness and Satisfaction, the group using the science kits experienced an improvement in learning environment and attitude scores, while the other two groups experienced a decline, with the group using a combination of a textbook and science kits experiencing a smaller decline than the textbook-only group.

In a study of learning environments in lower-secondary mathematics classrooms in Brunei Darussalam, the MCI was validated in a non-Western country (Majeed, Fraser, & Aldridge, 2002). Results regarding gender differences were consistent with earlier research in indicating that boys and girls perceived the same learning environment differently (Fisher, Henderson, & Fraser, 1997; Wong & Fraser, 1996). The MCI scale of Satisfaction was used as a dependent variable, while the three other scales (Cohesiveness, Difficulty, and Competition) were independent variables. Statistically significant associations were found between Satisfaction and the three MCI scales.

When a revised version of the MCI was used to evaluate the school environment (Sink & Spencer, 2005), the original My Class Inventory-Short Form was found to have some psychometric limitations. A revised MCI-SF was found to be valid and reliable when used with upper-elementary American students. The original 25-question, five-scale MCI-SF was revised to an 18-question, four-scale instrument. The original scales of Satisfaction, Cohesion, Competitiveness, and Friction were kept. The Difficulty scale, as well as some problematic items, was removed. The resulting instrument was used with a sample of approximately 3000 Grades 3–5 students. Elementary-school counselors can use the revised MCI-SF to evaluate the climate in the classrooms that they serve and thereby evaluate how they are influencing students and the climate of the school.

2.3.6 Questionnaire on Teacher Interactions (QTI)

The QTI was created for researchers and teachers for assessing student–teacher relationships in classrooms (Wubbels, 1993; Wubbels & Brekelmans, 1998, 2012; Wubbels, Créton, Levy, & Hooymayers, 1993). The premise is that the behavior of students influences the behavior of the teacher, and the behavior of the teacher influences the behavior of the students. The QTI was originally developed in the Netherlands for work with senior high school students, but it has since been cross-validated internationally (Wubbels & Brekelmans, 2012) and has been adapted to assess teachers' perceptions of a principal's interactions with teachers (Fisher & Cresswell, 1998). There are 77 items distributed unevenly across eight scales in the original version (Wubbels, 1993). All of the scales of the QTI can be classified as Moos' Relationship dimension (Fraser, 2012). The questionnaire uses a five-point frequency scale for each item about student–teacher interactions.

The QTI was developed based on a model for interactional teacher behavior that involves dimensions of Influence (Dominance–Submission) and Proximity (Opposition–Cooperation), each of which can be represented on an axis of a two-dimensional orthogonal system. The two dimensions underlie eight types of teacher behavior – student responsibility/freedom, understanding, helping/friendly, leadership, strict, admonishing, dissatisfied, and uncertain. Typical items are "She/he gives a lot of free time" (Student Responsibility and Freedom behavior) and "She/he gets angry" (Admonishing behavior). The eight scale scores from the QTI can be graphed using a polar coordinate system to create a spider web graph. A higher score for a given dimension results in a larger area of the corresponding sector being shaded (see Figure 2.1).

Based on research using the QTI, Wubbels and Brekelmans (2012) have several recommendations for improving science education. When communicating with students, both verbally and non-verbally, teachers' behaviors should be characterized by qualities of leadership, helpful/friendly, and understanding, while maintaining visual and verbal control. Teachers should also be reflective in their teaching and use questionnaires to get feedback from students about relationships in the classroom. From a professional perspective, staff development should focus on changing teacher behavior more than teacher attitudes. Teachers should focus on self-behavior when undesirable classroom situations arise. This includes being aware of expectations for different students that can result in lower performance because of lower expectations.

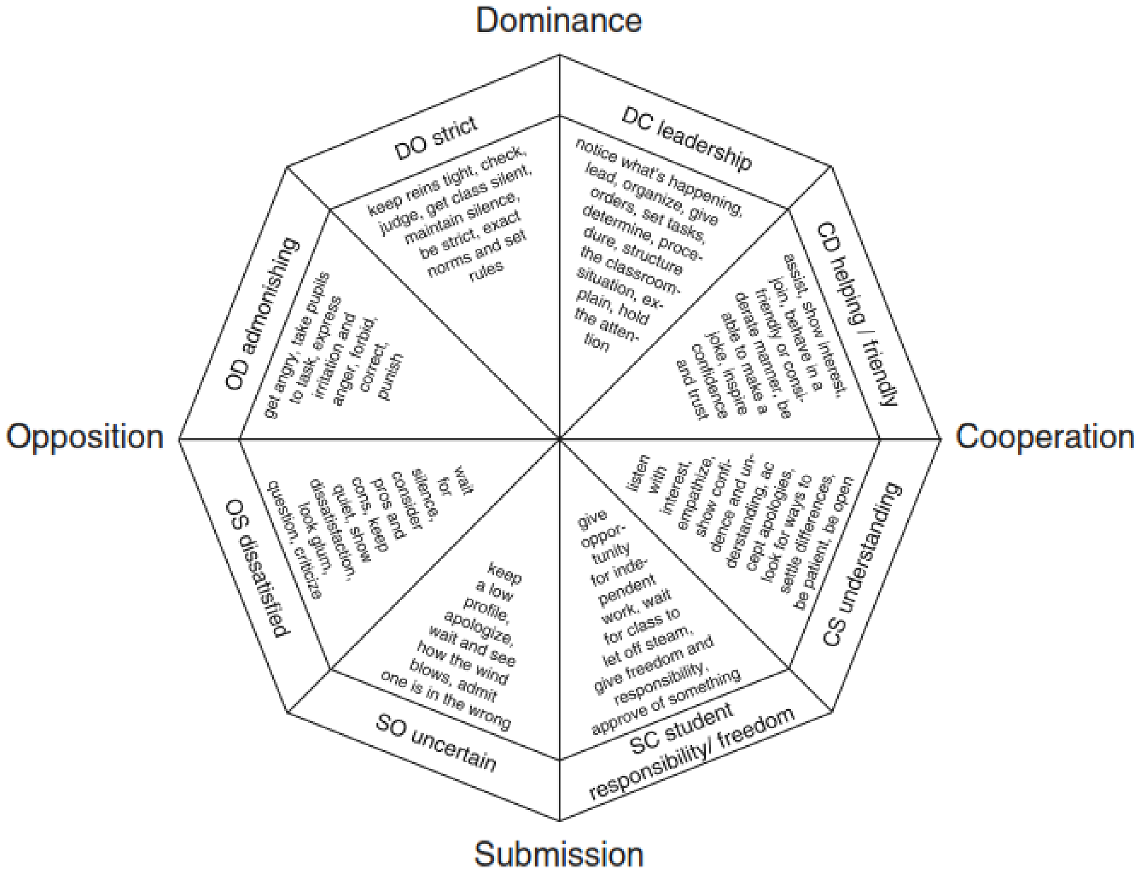

Figure 2.1 Model for Interpersonal Teacher Behavior (Wubbels & Brekelmans, 2012)

The QTI was found to be valid at the university level in Indonesia when modified and translated into the Indonesian language (Fraser, Aldridge, & Soerjaningsih, 2010). Attitudes towards computers were investigated as an outcome of the learning environment. The sample consisted of 422 students from research methods classes in two departments (Computer Science and Management) that were perceived as being different in their difficulty, learning strategies, and content. When compared to students in Computer Science courses, students in Management courses tended to be less motivated and not as academically strong. Students enrolled in Management courses had more favorable perceptions of their lecturers' interpersonal behaviors than did those enrolled in Computer science, particularly for Leadership, Helping/Friendly, and Understanding behaviors.

Along with the MCI, Goh and Fraser (1998) used the QTI (Primary) with 1512 students (ages 10–11 years) in 39 Singaporean mathematics classes in 13 government coeducational primary schools. The QTI (Primary) incorporates modifications to the original and short forms to make them more appropriate for younger students – language was modified to lower the reading level and the five-point response scale was reduced to a three-point scale. Better achievement and student attitudes were found in classes with more teacher Leadership, Helping/Friendly, and Understanding behaviors and less Uncertain behavior. Both interpersonal teacher behavior and classroom climate made a sizable and unique contribution to variance in students' attitudes, but not to student achievement.

The QTI (Primary) was validated with 3104 students (Years 4–6) in 136 classes in 25 primary schools in Brunei Darussalam (Scott & Fisher, 2004) after it was translated into Standard Malay and modified to meet the cultural and language needs of the students, creating the Questionnaire on Teacher Interaction (Elementary) – QTIE. Students had favorable perceptions of their teachers' interpersonal behaviors in terms of Leadership, Helping/Friendly Understanding, and Strict behaviors, but this was less so in terms of Student Responsibility/Freedom, Uncertain, and Admonishing behaviors. There were statistically significant associations between all eight scales of the QTIE and students' Enjoyment of Science Lessons and six of the eight QTIE scales were statistically significantly associated with achievement – Leadership, Helping/Friendly, Understanding, Strict, Student Responsibility/Freedom, and Admonishing.

2.3.7 Science Laboratory Environment Inventory (SLEI)

The SLEI was developed to assess the unique classroom learning environment of science laboratory classes at the senior high school and post-secondary levels when laboratory work is conducted in a separate classroom (Fraser, Giddings, & McRobbie, 1992). The questionnaire has a frequency response (Almost Never, Seldom, Sometimes, Often, and Very Often) and 35 questions evenly distributed across five scales. The scales of the SLEI can also be classified into Moos' three dimensions – Relationship (one scale), Personal Development (two scales), and System Maintenance and Change (two scales). The instrument was field tested and validated simultaneously in six countries (USA, Canada, England, Australia, Israel and Nigeria) with a sample of 5477 students in 269 classes (Fraser & McRobbie, 1995; Wong & Fraser, 1995). Later it also was cross-validated in Australia by Fisher, Henderson and Fraser (1997).

A modified version of the SLEI was used in conjunction with an attitude questionnaire based on the Fennema-Sherman Science Attitude Scales (Fennema & Sherman, 1976) to evaluate the use of innovative anthropometric activities in terms of the learning environment and the student outcomes of attitudes and achievement (Lightburn & Fraser, 2007). The modified SLEI consisted of four scales (Student Cohesiveness, Integration, Rule Clarity, and Material Environment) with six items each. The attitude instrument also consisted of four scales (Personal Confidence about Science, Usefulness of the Subject Matter, Perception of Teachers' Attitudes, and Attitude to Scientific Inquiry) consisting of six items each. The questionnaires were found to be valid and reliable with a sample of 761 students in 25 high-school classes in Florida. There were statistically significant changes between pretest and posttest in achievement, attitudes and learning environment when compared with a control group.

The SLEI and four scales from the TOSRA (Social Implications of Science, Normality of Scientists, Attitude to Scientific Inquiry, and Interest in Science) were translated into the Korean language and were found to be valid, reliable, and able to differentiate between the perceptions of students in different classes (Fraser & Lee, 2009). The sample consisted of 439 high school science students in one of three streams (science-independent, science-oriented, and humanities). With the individual used as the unit of analysis, there was a statistically significant correlation between two TOSRA scales (Social Implications of Science and Attitude to Scientific Inquiry) and the SLEI scale of Open-Endedness. There was also a statistically significant correlation between the two TOSRA scales of Normality of Scientists and Interest in Science and the SLEI scale of Material Environment. Generally students in the science-independent stream had the most favorable perceptions of their laboratory classroom environments when compared with students in the other two streams.

Using a chemistry-centric version of the SLEI and TOSRA, the Chemistry Laboratory Environment Inventory (CLEI) and Questionnaire on Chemistry Related Attitudes (QOCRA), respectively, Wong and Fraser (1996) investigated associations between students' perceptions of their chemistry laboratory classroom environment and their attitudes towards chemistry. A sample of 1592 Grade 10 chemistry students in 56 classes in 28 coeducational government schools in Singapore were administered the actual and preferred versions of the CLEI and the QOCRA. In all three instruments the word 'science' was changed to 'chemistry'. In addition, the three TOSRA attitude scales were changed to Attitude to Scientific Inquiry in Chemistry, Adoption of Scientific Attitudes in Chemistry, and Enjoyment of Chemistry Lessons. All five CLEI scales were associated significantly with each of the three attitude scales. In particular, Integration and Rule Clarity were strong and consistent predictors of student attitudes.

In a later study, Singaporean students' perceptions of their chemistry laboratory classroom environments and their interactions with their chemistry teachers, together with their attitudes towards chemistry, were investigated by administering four questionnaires – CLEI (actual and preferred versions), QTI, and QOCRA (Quek, Wong, & Fraser, 2005). A sample of 497 Grade 10 chemistry students in 18 classes in three independent single-sex schools in Singapore were distributed between two streams, namely, Gifted (GEP) or non-gifted (Express). For the CLEI, Open-Endedness was a statistically significant independent predictor of all three attitude scales, while Student Cohesiveness was a statistically significant independent predictor of Adoption of Scientific Attitudes in Chemistry, and Rule Clarity was a significant independent predictor of Attitude to Scientific Inquiry in Chemistry. For the QTI, however, only Enjoyment of Chemistry Lessons was significantly related to QTI scales. In addition, the CLEI and the QTI made unique and independent contributions to variance in attitudes.

2.3.8 Constructivist Learning Environment Survey (CLES)

The CLES assesses the degree to which a particular classroom environment is consistent with constructivist epistemology (P. C. Taylor, Fraser, & Fisher, 1997). The instrument can be used to help teachers to reflect on their assumptions and to adjust their teaching practices. The CLES has been used to compare the effectiveness of alternative educational programs (Nix, Fraser, & Ledbetter, 2005). The questionnaire uses a frequency response scale (Almost Never, Seldom, Sometimes, Often, and Very Often) for responding to its 35 questions that are evenly distributed across five scales. The scales of the CLES can be classified using Moos' three dimensions – Relationship (two scales), Personal Development (two scales), and System Maintenance and Change (one scale).

The actual and preferred versions of the CLES were translated into the Korean language and found to be valid and reliable (H. B. Kim et al., 1999). The CLES and a seven-item Attitude to This Class scale, based on the TOSRA, were administered to 1083 students in 24 classes in 12 schools with a Grade 10 class and a Grade 11 class from each school. Grade 10 students studied general science with a constructivist approach, while Grade 11 studied a specific science, such as physics, chemistry, biology, or earth science with strong academic content. There were statistically significant correlations between the scales of Personal Relevance, Shared Control, and Student Negotiation and student attitudes in Grade 10, while Personal Relevance, Uncertainty, and Shared Control were statistically significantly related to student attitudes for Grade 11. For Grades 10 and 11, Personal Relevance was the strongest independent predictor of students' attitudes towards their science classes. In a subsequent study in Korea, a modified 25-item five-scale version of the CLES in the Korean language was validated with 440 science students in 18 grade 10 and 11 classes. Also, this study replicated past findings of associations between classroom environment and students' attitudes to science.

In Singapore, the CLES was used to evaluate the effectiveness of using a Mixed Mode Delivery (MMD) framework in terms of classroom learning environment and student attitudes (Koh & Fraser, 2014). A modified version of the CLES consisting of five scales (Personal Relevance, Uncertainty, Critical Voice, Shared Control, and Negotiation) was administered to 2216 secondary-school students taught by preservice teachers in an MMD group and 991 students in a control group taught by preservice teachers using primarily traditional teacher-centered methods (TA). Both groups were business-studies students. The CLES was found to be valid, reliable, and capable of differentiating between the perceptions of students in the different classes. While both groups of students perceived a gap between their actual environment and their preferred environment, the effect sizes for actual–preferred differences were considerably larger for the TA students than for the MMD students.

The CLES was translated into Mandarin in a cross-national study in Taiwan and Australia and was found to be valid, reliable, and capable of differentiating between the perceptions of students in different classes (Aldridge, Fraser, Taylor, & Chen, 2000). With the individual as the unit of analysis, and for both Australia and Taiwan, there were positive and statistically significant independent associations between student attitudes and Personal Relevance, Shared Control, and Student Negotiation. However, it is worth noting the authors found that students in Taiwan and Australia did not always interpret statements in the same way.

In South Africa, a modified version of the CLES (actual and preferred) was used with 1804 mathematics students in Grades 4–9 in 43 classes in six schools with 29 teachers (Aldridge, Fraser, & Sebela, 2004). The instrument was found to be valid and reliable, as well as being able to significantly differentiate between the perceptions of students in different classes. The study used the CLES in teacher action research aimed at increasing the constructivist emphasis of two teachers' classrooms. The feedback from the initial administration of the CLES guided teachers in making their classrooms more constructivist in nature as measured by pre–post changes. In addition, actual posttest scores were close to what students would prefer.

When the CLES was translated into Spanish and administered in English and Spanish to 739 Grade K–3 students in Miami, it was found to be valid, reliable, and able to differentiate between the perceptions of students in different classes (Peiro & Fraser, 2009). Associations between the nature of the classroom environment and students' attitudes were found to be strong and positive. A three-month classroom intervention led to educationally-important changes in the classroom environment.

2.4 What Is Happening In this Class? (WIHIC)

Because the WIHIC was used in my study to assess students' perceptions of the classroom learning environment, it is discussed in detail in this section. The WIHIC (Aldridge & Fraser, 2000; Aldridge, Fraser, & Huang, 1999; Dorman, 2003) combines scales from previous instruments and includes contemporary dimensions such as constructivism and equity. The WIHIC, along with the SLEI and CLES, are more relevant to student-centered as opposed to teacher-centered classrooms (Fraser, 1998b, 2012; Koul & Fisher, 2005).

There are 56 items in the seven scales of the WIHIC: Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, and Equity. The WIHIC has a personal form which can be used to identify differences between subgroups based on factors such as gender, ethnicity, or socioeconomic level. The personal form is useful for an understanding based on these subgroups and it uses 'I' instead of the 'students' when referring to who is experiencing the classroom environment (Fraser & Tobin, 1991). In addition, students tended to have a more positive view when responding to the whole-class survey than when responding to the personal form (Yeo, 2002). Table 2.2 provides a scale description and sample item for each scale.

Table 2.2 Scale Description and Sample Item for Each Scale of the WIHIC

Scale Name	Scale Description	Sample Item
Student Cohesiveness	The extent to which students know, help, and are supportive of one another.	I make friends with other students in this class.
Teacher Support	The extent to which the teacher helps, befriends, trusts, and is interested in students.	The teacher helps me when I have trouble with the work.
Involvement	The extent to which students have attentive interest, participate in discussions, do additional work, and enjoy the class.	My ideas and suggestions are used during classroom discussions.
Investigation	The extent to which skills and processes of inquiry and their use in problem solving and investigation are emphasized.	I do investigations in this class.
Task Orientation	The extent to which it is important to complete activities plan and to stay on the subject matter.	Getting a certain amount of work done is important to me.
Cooperation	The extent to which students cooperate rather than compete with one another on learning tasks.	I cooperate with other students when doing assigned work.
Equity	The extent to which students are treated equally by the teacher.	The teacher gives as much attention to my questions as to other students' questions.

Based on Afari et al. (2013)

When the WIHIC has been used in numerous studies (Aldridge & Fraser, 2000; Dorman, 2003; H. B. Kim et al., 2000; Koul & Fisher, 2005), it has been shown it to be valid and reliable for assessing the nature of classroom environments. The WIHIC has been extensively validated in both Western and non-Western countries, with the findings from non-Western countries are generally consistent with results from Western contexts. These studies reported strong associations between classroom environment and student outcomes for most scales (Fraser, 2012). Statistical analyses have established the cross-cultural validity of the WIHIC (Aldridge et al., 1999) in Australia and Taiwan and in Australia and Indonesia (Fraser, Aldridge, & Adolphe, 2010).

The following Sections 2.4.1 to 2.4.4 review the use of the WIHIC internationally, specifically in Australia, Asia, North America, and Africa and the Middle East. This is followed by Sections 2.5.1 to 2.5.4 reviewing the research on classroom learning environments with a special focus on the WIHIC.

2.4.1 Use of WIHIC in Australia

In a study of both physical and psychosocial learning environments, Zandvliet and Fraser (2005) used the WIHIC in computer networked classrooms. The sample consisted of 1404 students in 81 high school classes in Australia and Canada. Five scales of the WIHIC, one scale of the TOSRA, and five scales of the Computerized Classroom Ergonomic Inventory (CCEI) were used. The WIHIC scales were Student Cohesiveness, Involvement, Autonomy/Independence, Task Orientation, and Cooperation; the TOSRA scale was Student Satisfaction; and the CCEI scales were Workspace Environment, Computer Environment, Visual Environment, Spatial

Environment, and Overall Air Quality. The scales of the WIHIC were found to have statistically significant associations with Student Satisfaction. In addition, the physical environment contributed to Student Satisfaction through its statistically significant independent link to the WIHIC scales.

Dorman (2008) also validated the actual and preferred forms of the WIHIC. In a study with 978 secondary students in Queensland, Australia, he found a large amount of score variance was explained by the scales rather than the forms. The instrument was validated using confirmatory factor analysis, as opposed to the typical exploratory factor analysis. Multitrait–multimethod modeling also supported the instrument's construct validity.

In a study combining items from the seven scales of the WIHIC and two scales (Satisfaction and Difficulty) from the MCI, Ly and Malone (2010) used a 56-item nine-scale instrument with 18 English-as-a-Second Language (ESL) geometry teachers in Southwest Sydney. The number of items in each scale varied from four to eight. The instrument was found to be valid and reliable. Positive associations were indicated between the learning environment and teachers' views of geometry instruction and the achievement of their classroom goals. In addition, teachers' perceptions of teaching geometry were positive.

In a cross-national study in Australia and Indonesia, a modified version of the WIHIC was used to investigate differences in perceptions of the learning environment between countries and genders (Fraser, Aldridge, & Adolphe, 2010). The sample consisted of 594 students in 18 classes in Indonesia and 567 students in

18 classes in Australia, making a total of 1161 students in 36 classes. The original eight-scale, 80-item WIHIC was translated into Bahasa Indonesian and administered to Grade 9 and 10 students in eight private coeducational schools (four each in Indonesia and Australia). Factor analysis resulted in 55 items in six scales (Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, and Equity). Each WIHIC scale differentiated significantly between classrooms for both Indonesian and Australian students. Indonesian students perceived their learning environment more positively than Australian students with respect to Involvement and Investigation. However, Australian students perceived their learning environment more positively than Indonesian students with respect to Task Orientation and Equity.

2.4.2 Use of WIHIC in Asia

Using Korean versions of the WIHIC and QTI (H. B. Kim et al., 2000) with 543 students in 12 Korean single-sex schools, students' attitudes towards science and their perceptions of the classroom learning environment were investigated. In addition to supporting the cross-cultural validity of the instruments when translated into Korean, each scale of both instruments was found to be reliable, valid, and able to distinguish between perceptions of students in different classrooms. There were significant positive attitude–environment relationships for most scales of the WIHIC. While boys perceived their learning environment, their teacher's interpersonal behavior, and their attitudes toward science class more positively than did girls, the interpretation was not clear because the boys and girls were not in the same schools.

A modified form of the WIHIC was translated into Indonesian and administered to 1400 students and their teachers in 16 schools in Indonesia (Wahyudi & Treagust, 2004). The Indonesian version was found to be valid and reliable as a measure of the classroom learning environment and was able to differentiate between the perceptions of students in different groups. In addition, there were significant differences between students' perceptions of the actual and preferred learning environment, and female students generally held more positive perceptions than males. Students, in general, also held less favorable perceptions than their teachers across all scales except Task Orientation, for which perceptions were similar. Rural students held less favorable perceptions than did urban and suburban students.

Koul and Fisher (2005) used the WIHIC to study differences between cultures, as determined by the language spoken at home, in student perceptions of the classroom environment. Differences in students' perceptions of their learning environment were associated with their cultural background. The 1021 Grade 9 and Grade 10 students came from 31 classes in seven different schools in Jammu, India. The diversity of the area is reflected in the diversity of the 13 languages spoken at home. Of these 13 languages, only four groups were large enough for analysis – Hindi (522), Kashmiri (221), Dogri (175), and Punjabi (82); the remaining 21 students were distributed among the other nine languages. The Kashmiri students had the most positive perceptions of their classroom environment, specifically for the scales of Student Cohesiveness, Task Orientation, Cooperation, and Equity. The Dogri students had the most negative perceptions of their classroom environment, specifically for the scales of Investigation, Task Orientation, Cooperation, and Equity. The authors attributed this to the value placed on education by each of these cultural groups:

generally Kashmiri value education and see it as a way to maintain ‘a relatively good life,’ while Dogri generally tend to have family businesses and see education as providing enough skills to run the business.

In two private schools in India, Smith (2013) explored the relationship between the learning environment and “students’ sense of life purpose and personal meaning” (p. 262). The sample consisted of 267 students aged 16 to 21 years in secondary and undergraduate education. A modified version of the WIHIC with six scales (Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Cooperation, and Equity), as well as with rewording to allow for school-level analysis (*In this school*… instead of *In this class*…), was used together with four scales of a Personal Meaning System (Purpose, Coherence, Choice/Responsibility, and Satisfaction with Education) that were combined to construct a global measure of concerns and attitudes towards life – Agentic Personal meaning (APM). All four scales of the WIHIC were found to have a significant relationship with Purpose and Coherence.

In Singapore, the WIHIC was modified for use with 250 adults attending classes in five computer education centers (Khoo & Fraser, 2008). The instrument was modified to include the six scales of Trainer Support, Involvement, Autonomy/Independence, Task Orientation, Equity, and Student Cohesiveness (which was removed to improve the factor structure). The researchers found that males perceived greater Trainer Support and Involvement, but females perceived more Equity. In addition, older students were generally more satisfied than younger students and older females perceived more Trainer Support than younger females.

The data analysis supported the WIHIC's validity, reliability, and ability to differentiate between classrooms.

Chionh and Fraser (2009) validated a seven-scale version of the WIHIC with 2310 Singaporean Grade 10 students in 75 geography and mathematics classes in 38 schools. The instrument was modified to include the eight scales of Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, Equity, and Autonomy/Independence (which was removed to improve the factor structure). Each student in the study responded to an actual and a preferred form for both their mathematics classroom and their geography classroom. For every scale of the WIHIC, an attitude scale (Enjoyment of Lessons, Leisure Interest, and Career Interest) or self-esteem scale was statistically significantly related to classroom learning environment for mathematics and geography. However, only two WIHIC scales (Student Cohesiveness and Task Orientation) were statistically significantly related to attitudes for geography; and three WIHIC scales (Student Cohesiveness, Task Orientation, and Equity) were significantly related to attitudes to mathematics. In addition, each of the seven WIHIC scales was a statistically significant independent predictor of at least one of the attitude or self-esteem scales. Teacher Support, Task Orientation, and Equity were significant and independent predictors of multiple attitudinal outcomes, while Student Cohesiveness was the strongest independent predictor of achievement.

Peer and Fraser (2015) also used scales from the WIHIC in an investigation of primary science classrooms in Singapore involving 1081 students in 55 classes. Attitudes were statistically significantly associated with scales from the WIHIC

(Involvement, Teacher Support, Investigation, Task Orientation and Cooperation). Significant gender differences emerged for Involvement, Teacher Support, Task Orientation and Cooperation; significant grade-level differences were found for Teacher Support, Task Orientation and Cooperation; and significant stream differences were present for Involvement and Cooperation. There were also significant stream–by–gender interactions for Task Orientation; significant grade–by–stream interactions for Investigation; and no significant grade–by–gender or stream–by–gender–by–grade interaction for any WIHIC scale.

Yang, Wang, and Kao (2012) used a Chinese translation of WIHIC with 113 Grade 6 students in Taiwan to study the influence of the use of Interactive Whiteboards (IAW) compared with traditional information communication technology (ICT) on learning and the learning environment in health and physical education classrooms. Students in the IWB group were found to have higher scores on all seven scales of the WIHIC, which the researchers attributed mainly to the physical size and interactive nature of the Whiteboard.

2.4.3 Use of WIHIC in North America

The WIHIC was used in an investigation of the effects of student, teacher, and school demographics on students' perceptions of their learning environment (den Brok, Fisher, Rickards, & Bull, 2006) among 665 California middle-school science students in 11 schools. The WIHIC was found to be valid and reliable, but only the scales of Student Cohesiveness, Task Orientation, and Involvement were able to differentiate between perceptions of students in different classrooms. Female students had more favorable perceptions of their science classroom environment than males. In addition, there was a positive association between the number of ethnic groups in the classroom and students' perceptions of Student Cohesiveness.

A modified three-scale version of the WIHIC was used to investigate middle-school mathematics classroom environments (Ogbuehi & Fraser, 2007) among 661 students in 22 classrooms in four inner-city Californian schools. The study focused on the effectiveness of innovative teaching strategies for improving the classroom environment, students' attitudes, and students' conceptual development. The classroom environment was measured using modified versions of the WIHIC and CLES, whereas attitudes were measured using modified versions of the TOMRA. There were moderate positive associations between the learning environment, especially as measured by the WIHIC dimensions of Involvement and Task Orientation, and students' attitudes to mathematics as measured by the TOMRA.

In an investigation of relationships between the learning environment and students' mathematics anxiety, as well as differences between the sexes in perceptions of learning environment and anxiety, Taylor and Fraser (2013) cross-validated the WIHIC and an updated Revised Mathematics Anxiety Rating scale with a sample of 745 high-school students in Southern California. Females perceived a more positive classroom environment and more anxiety about mathematics evaluation than males, but males perceived more anxiety about mathematics learning than females. Some statistically significant associations were found between learning mathematics anxiety and learning environment scales.

With a sample of 520 Grade 4 and 5 students and 120 of their parents in South Florida, Allen and Fraser (2007) found a modified version of the WIHIC to be valid, reliable, and able to differentiate between the perceptions of students in different classrooms. The students from 22 classes and some of their parents completed an actual version and a preferred version. The parents also completed an actual version and a preferred version; however, the parents were all from the same school. The wording was simplified and the number of items in the WIHIC was reduced to be more appropriate for these students. In addition, the parents' form was reworded to reflect perceptions of the parent. Six of original WIHIC scales were used – Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Equity, and Investigation. Associations between achievement and classroom environment were stronger for parents than for students, with associations being weak for students. However, the associations between student attitudes and the Task Orientation and Investigation scales were somewhat stronger. In addition, associations between students' attitudes and parents' perceptions of the learning environment were relatively weak, except for the Task Orientation scale.

When the WIHIC was used with 1434 Grade 7 and 8 students in 71 coeducational classrooms in 18 schools (Wolf & Fraser, 2008), it was found to be valid, reliable, and able to differentiate between the perceptions of students in different classrooms. Inquiry and non-inquiry laboratory teaching was compared in terms of the classroom learning environment, attitudes to science, and achievement among Grade 7 physical science students. A subsample of 165 Grade 7 students in eight classes in Long Island, New York conducted laboratory experiments based on the science curriculum. The eight classes were taught by two teachers, with each teacher teaching two classes using inquiry laboratory activities and two classes using non-inquiry laboratory activities. Students in the inquiry classrooms perceived a statistically significantly greater amount of Student Cohesiveness than did students in the non-inquiry classes. In addition, females perceived more Student Cohesiveness and Cooperation, and less Teacher Support and Investigation, than did males. Females benefited more than males from non-inquiry activities in terms of attitudes to science and the learning environment scales of Task Orientation, Cooperation, and Equity; however, males benefited more than females from inquiry activities in terms of attitudes to science and the scales of Task Orientation, Cooperation, and Equity. Although there were strong and consistent associations between learning environment scales and student attitudes, associations between the learning environment and achievement were weaker.

Martin-Dunlop and Fraser (2008) used the WIHIC with 525 female preservice elementary teachers in 27 classes in a large urban university in Southern California. The purpose was to evaluate the effectiveness of an innovative science course for improving preservice elementary teachers' perceptions of the laboratory learning environment. Four scales of the WIHIC (Student Cohesiveness, Instructor Support, Investigation, and Cooperation) were used with two scales of the SLEI (Open-Endedness and Material Environment) and one scale from the TOSRA (Enjoyment of Science Lessons). During the course, students' perceptions for all four scales of the WIHIC and both scales of the SLEI showed positive gains. Associations between student attitudes (Enjoyment of Science Lessons) and the learning environment were high, especially for the Instructor Support scale.

In a study comparing self-reported learning styles and the learning environment preferences of education and nursing students, Roberge, Gagnon, and Oddson (2011) used the visual, aural, read/write, kinesthetic (VARK) learning style inventory and the preferred form of the WIHIC in English and French. A sample of 101 predominantly-female students with at least two years post-secondary school experience consisted of 80 education students and 21 nursing students. In terms of the WIHIC scales, education students preferred a more positive learning environment than the nursing students preferred. Both student groups preferred a classroom environment with high level of Task Orientation.

In a study of American kindergarten students' and their parents' perceptions of the actual and preferred learning environment, Robinson and Fraser (2013) used a modified version of the WIHIC appropriate for young students. The sample consisted of 172 kindergarten students and 78 of their parents in six classes in an elementary school in a large urban district in South Florida. The original WIHIC was reduced to 16 items in the four scales of Teacher Support, Involvement, Cooperation, Equity, and Student Cohesiveness (which was removed to improve the factor structure). The four scales were found to be valid and reliable and able to differentiate between perceptions of students in different classrooms. Both students and parents preferred a more positive learning environment than was perceived. However, parents perceived a more favorable actual learning environment than students perceived, while students preferred a more favorable learning environment than parents preferred. Teacher Support, Involvement, Cooperation and Equity were significantly and positively related to achievement, Equity was significantly and positively related with Adoption of Science Attitudes, and Teacher Support and Equity were significantly and positively related to Attitude to Scientific Inquiry. In addition, all four learning environment scales were significantly and positively related to science achievement.

In evaluating the effectiveness of National Board Certified (NBC) teachers in terms of their students' perceptions of their classroom environments, their attitudes, and their achievement, Helding and Fraser (2013) used a slightly modified form of the WIHIC, the Enjoyment of Science Lessons scale of the TOSRA, and the science component of the Florida Comprehensive Achievement Test. The sample consisted of 443 Grade 8 and 10 science students in 21 classes taught by NBC teachers and 484 Grade 8 and 10 science students in 17 classes taught by non-NBC teachers in South Florida (a total of 927 students in 38 classes in 13 schools). The WIHIC, modified by rewording a small number of statements, maintained its validity, reliability, and ability to differentiate between the perceptions of students in different classrooms. The learning environment was strongly related to student outcomes, and more strongly to students' attitudes than to achievement. Differences between students of NBC teachers and of non-NBC teachers were statistically significant for the five scales of Teacher Support, Involvement, Task Orientation, Investigation and Cooperation and for the Enjoyment of Science Lessons scale. However, differences between the two groups were nonsignificant for the scales of Student Cohesiveness and Equity and for achievement.

In an investigation of perceptions of the learning environment in science and mathematics classrooms in which laptop computers were used in Ontario, Fraser and Raaflaub (2013) used the WIHIC with 1173 Grade 7–12 students. Their data supported the factorial validity and internal consistence reliability of the WIHIC and attitude scales. Large and statistically significant differences were reported for differences between preferred and actual classroom learning environments. Science students reported a more positive learning environment in terms of perceptions and attitudes than did mathematics students; males reported more positive attitudes, but females held more favorable perceptions of the learning environment.

2.4.4 Use of WIHIC in Africa/Middle East

The WIHIC has been translated into IsiZulu for use in South Africa at the primary-school level (Aldridge, Fraser, & Ntuli, 2009). A modified version of the WIHIC (WIHIC-Primary) was administered to 1077 mathematics students in Grades 4 to 7 in 31 rural and semi-rural schools. Students responded to both the actual and preferred versions in order to provide feedback to guide improvements in the teaching practices of teachers engaged in distance in-service teacher training. Modifications to the WIHIC included reducing the number of scales to six, removing the Investigation scale and reducing the number of items from eight per scale to six, giving a total of 36 items. The language of questions was simplified to be more appropriate for primary students and *student* was changed to *learner* as recommended by the South African Department of Education. Finally, the WIHIC was translated into IsiZulu for students in Grades 4 and 5 and the five-point frequency response scale was reduced to a three-point scale. Factor analysis confirmed a four-scale structure (Teacher Support, Involvement, Task Orientation, and Equity) with 19 items. The WIHIC-Primary was found to be valid and reliable and was able to differentiate between the perceptions of students in different classrooms. Learners preferred a more favorable environment than was perceived to be present for each of the four scales, and actual–

preferred differences were statistically significant for Involvement, Task Orientation, and Equity.

In a Ugandan study of secondary-school mathematics students, Opolot-Okurut (2010) used a modified version of the WIHIC to study associations between student perceptions of the learning environment and motivation towards mathematics for a high-performing (HP) and a low-performing (LP) school. The sample consisted of 81 students (19 males and 62 females) aged 14 to 20 years in government-aided schools. The modified WIHIC contained eight items in each of the five scales of Teacher Support, Student Involvement, Task Orientation, Cooperation, and Equity. The instrument was found to be valid and reliable. In addition, all scales of the WIHIC had statistically significant positive correlations with motivation for the HP school. Similarly, scales of the WIHIC had significant positive correlations with motivation for the LP school on all scales but Cooperation. However, students in the LP school perceived Teacher Support and Student Involvement as occurring more frequently than did students in the HP school.

An Arabic version of a modified WIHIC, called the Learning Environment Questionnaire (LEQ), and an Attitudes Toward Biology Questionnaire (ATBQ) were pilot tested with 190 Grade 11 students to ensure comprehensibility, validity, and reliability (Zeidan, 2010). The LEQ consisted of the four scales of Student Cohesiveness, Instructor Support, Investigation, and Cooperation that were used with a different sample of 190 Grade 11 students in the district of Tulkarm, Palestine. The students were all enrolled in the science stream in single-sex schools and proportionately represented the Grade 11 population in regards to gender (male/female) and residency (city/village). There was a significant positive correlation between attitudes toward biology and the learning environment. As well, differences in attitudes towards biology and in perceptions of the learning environment were significant for gender (favoring females) and nonsignificant for residency.

Three WIHIC scales, a scale from the CLES, and a scale from the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) were administered in Arabic and English to 763 college students in 82 classes at Dubai Women's College in the United Arab Emirates (UAE) (MacLeod & Fraser, 2010). The WIHIC scales were Teacher Support, Involvement, and Cooperation; the CLES scale was Personal Relevance; and the TROFLEI scale was Computer Usage. Students responded to both an actual and a preferred form. The modified questionnaire was found to be valid, reliable, and able to differentiate between the perceptions of students in different classrooms. Students preferred a more favorable classroom environment on all scales than the environment that they perceived as being present.

In a study in the UAE, Afari, Aldridge, Fraser, and Khine (2013) used the WIHIC to assess the effectiveness of using Jeopardy-type games for improving students' perceptions of their learning environment and their attitudes towards mathematics. For a sample of 352 students in 33 college-level mathematics classes in three colleges, eight classes (90 students) were exposed to mathematical games as an instructional strategy. Students were administered a pretest and posttest of a modified version of the WIHIC in English and Arabic. Five scales of the WIHIC were selected (Student Cohesiveness, Teacher Support, Involvement, Cooperation, and Equity) and one scale of the CLES (Personal Relevance). The instrument was translated into Arabic and some phrasing was modified to be more appropriate for the UAE setting. The modified Arabic version of the WIHIC was found to be valid, reliable, and able to differentiate between the perceptions of students in different classrooms. With the individual as the unit of analysis, all of the learning environment scales were positively and statistically significantly related to attitudes; however, with the class mean as the unit of analysis, none of the learning environment scales were statistically significantly related to attitudes.

2.5 Research Involving Classroom Environment Instruments

Fraser (1998a, 2012) identified several types of research applications of classroom learning environment instruments: 1) associations between student outcomes and environment, 2) evaluation of educational innovations, 3) teachers' attempts to improve classroom and school environments, 4) differences between students' and teachers' perceptions of the environment, 5) combining quantitative and qualitative methods, 6) school psychology, 7) links between educational environments, 8) cross-national studies, 9) transitions between different levels of schooling, and 10) typologies of classroom environments. Each of the above areas is discussed below.

A review of associations between student outcomes and the learning environment illuminates how students' perceptions of their environment impact such outcomes as attitudes, achievement, and self-esteem (Section 2.5.1). In evaluating the effectiveness of educational innovations, learning environment instruments can identify those innovations that improve the learning environment (Section 2.5.2). The use of action research and learning environment instruments can help teachers to develop and identify strategies to improve their classroom environment (Section 2.5.3). Classroom learning environment instruments can also be used by teachers to compare their own perceptions with their students' perceptions of the same learning environment (Section 2.5.4). When learning environment instruments are used in combination with qualitative methods, the combination can provide insights unavailable from the use of instruments alone (Section 2.5.5). School counselors can use learning environment instruments to evaluate school counseling programs (Section 2.5.6).

The link between school, home, and peer environments and the classroom environment can also be considered (Section 2.5.7). In addition, cultural factors that affect perceptions of the learning environment can be researched through cross-national studies (Section 2.5.8). When students transition from close-knit primary schools to departmentally-organized middle/lower secondary schools, classroom environment instruments can be used to identify perceived changes in the learning environment (Section 2.5.9). Learning environment instruments can also be used to categorize classrooms based on different typologies of classrooms (Section 2.5.10).

2.5.1 Associations between Student Outcomes and Environment

Early research on learning environments explored associations between student outcomes and the classroom environment. This continues to be an area of considerable interest as researchers investigate associations between a variety of student outcomes and their learning environment. Associations between outcomes and perceptions of the classroom learning environment cut across languages, countries, and grade levels (Fraser, 2012).

In a meta–analysis aimed at estimating the sign and size of correlations between student perceptions of classroom learning environment and learning outcomes, Haertel, Walberg, and Haertel (1981) analyzed 734 correlations from 12 studies involving 823 classes in eight areas (general science, life sciences, physical sciences, mathematics, social sciences, humanities, general studies, miscellaneous) and representing 17,805 students in four countries (USA, Canada, Australia, and India). All 12 studies employed the Learning Environment Inventory in its original, a simplified, or a shortened form. Learning outcomes and gains were positively associated with Cohesiveness, Satisfaction, Task Difficulty, Formality, Goal Direction, Democracy, and the Material Environment, but negatively associated with Friction, Cliqueness, Apathy, and Disorganization. Regression analysis showed that the magnitudes of the correlations depended on specific scales, level of aggregation, and nation, but not on sample size, subject matter, domain of learning outcome (cognitive, affective, or behavioral), or the use of statistical adjustments for ability and pretests. In another synthesis of research, (Wang, Haertel, & Walberg, 1993) analyzed 179 handbook and annual review chapters, as well as other reviews related to learning and affective outcomes. The analysis suggested that the “quality and quantity of instruction are roughly equal in importance to student characteristics and out-of-school contextual items” (p. 94). In contrast, those variables most affected by policy, state-, district-, and school-level factors had markedly lower importance.

Wong and Fraser (1996) and Wong, Young, and Fraser (1997) reported significant associations between classroom environment and the outcomes of student attitudes using the Chemistry Laboratory Environment Inventory (CLEI), which is a modified version of the SLEI, and the TOSRA. Significant associations were found between the chemistry laboratory classroom environment and chemistry-related attitudes for 1592 final-year secondary school students in 56 chemistry classes and 28 government schools in Singapore. In a subsequent study in Singapore with the CLEI and the QTI, Quek, Fraser, and Wong (2005) reported associations between students' attitudes towards chemistry and their laboratory classroom environment and the interpersonal behavior of their teachers. Statistically significant associations were found between the laboratory classroom environment and students' attitude toward chemistry.

Fisher, Henderson, and Fraser (1997) used the SLEI and TOSRA to reveal associations between the laboratory learning environment and student outcomes of attitude, achievement, and practical performance. Numerous positive associations with the nature of the chemistry laboratory classroom and students' science-related attitudes were reported for 489 students in 28 biology classes in Tasmania.

Afari, Aldridge, Fraser, and Khine (2013) reported associations between the learning environment and attitudes towards mathematics for 352 college mathematics students in 33 classes in the United Arab Emirates.

Table 2.3 provides an overview of how extensively the WIHIC has been used by presenting 23 studies using the WIHIC; most of these studies involved investigation of associations between learning outcomes and classroom environment. The first six studies show that the WIHIC was used in cross-national studies in Australia and each of four other countries – Taiwan (Aldridge & Fraser, 2000; Aldridge et al., 1999), the United Kingdom (Dorman, 2003), Indonesia (Fraser, Aldridge, & Adolphe, 2010), and Canada (Zandvliet & Fraser, 2004, 2005). The next six studies involved administering the WIHIC in English in Singapore (Chionh & Fraser, 2009; Khoo & Fraser, 2008), India (Koul & Fisher, 2005), Australia (Dorman, 2008), Canada (Fraser & Raaflaub, 2013) and South Africa (Aldridge et al., 2009). The next four studies involved translating the WIHIC into Korean (H. B. Kim et al., 2000), Indonesian (Wahyudi & Treagust, 2004), and Arabic (Afari et al., 2013; MacLeod & Fraser, 2010). The final nine studies were conducted in the USA in California (den Brok et al., 2006; Martin-Dunlop & Fraser, 2008; Ogbuehi & Fraser, 2007; B. A. Taylor & Fraser, 2013), New York (Wolf & Fraser, 2008), and Florida (Allen & Fraser, 2007; Helding & Fraser, 2013; Pickett & Fraser, 2009; Robinson & Fraser, 2013). Although Table 2.3 is based on Fraser (2012), it has been updated and expanded to include some additional recent studies.

Table 2.3 Overview of Studies Involving Use of the WIHIC

Reference(s)	Country(ies)	Language(s)	Sample(s)	Factorial Validity and Reliability	Associations with Environment for:	Unique Contributions
Aldridge et al. (1999) Aldridge and Fraser (2000)	Australia Taiwan	English Mandarin	1,081 (Australia) and 1,879 (Taiwan) junior high science students in 50 classes	✓	Enjoyment	Mandarin translation Combined quantitative and qualitative methods
Dorman (2003)	Australia UK Canada	English	3,980 high school students	✓	NA	Confirmatory factor analysis substantiated
Fraser et al. (2010)	Australia Indonesia	English Bahasa	567 students (Australia) and 594 students (Indonesia) in 18 secondary science classes	✓	Several attitude scales	Differences were found between countries and sexes.
Zandvliet and Fraser (2004, 2005)	Australia Canada	English	1,404 students in 81 networked classes	✓	Satisfaction	Involved both physical (ergonomic) and psychosocial environments
Chionh and Fraser (2009)	Singapore	English	2,310 grade 10 geography and mathematics students	✓	Achievement Attitudes Self-esteem	Differences between geography and mathematics classroom environments were smaller than between actual and preferred environments.
Khoo and Fraser (2008)	Singapore	English	250 working adults attending computer education courses	✓	Satisfaction	Adult population Males perceived more trainer support and Involvement but less equity.
Koul and Fisher (2005)	India	English	1,021 science students	✓	NA	Differences in classroom environment according to student cultural background.

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Dornan (2008)	Australia	English	978 secondary school students	✓	NA	Multitrait-multimethod modeling validated actual and preferred forms.
Fraser and Raaflaub (2013)	Canada	English	1173 Grade 7–10 students	✓	Attitudes	Large differences between preferred and actual classroom learning environments. Learning environment more positive for science than mathematics More positive attitudes for males, but more favorable perceptions of learning environment for females
Aldridge et al. (2009)	South Africa	English	1,077 grade 4-7 students	✓	NA	Pre-service teachers undertaking a distance- education program used environment assessments to improve teaching practices.
Kim et al. (2000)	Korea	Korean	543 grade 8 science students in 12 schools	✓	Attitudes	Korean translation Sex differences in WIHIC scores
Wahyudi and Treagust (2004)	Indonesian	Indonesian	1,400 lower-secondary science students in 16 schools	✓	NA	Indonesian translation Urban students perceived greater cooperation and less teacher support than suburban students.
MacLeod and Fraser (2010)	UAE	Arabic	763 college students in 82 classes	✓	NA	Arabic translation Students preferred a more positive actual environment
Afari et al. (2013)	UAE	Arabic	352 college students in 33 classes	✓	Enjoyment Academic efficacy	Arabic translation Use of games promoted a positive classroom environment
den Brok et al. (2006)	California, USA	English	665 middle-school science students in 11 schools	✓	NA	Girls perceived the environment more favorably
Martin-Dunlop and Fraser (2008)	California, USA	English	525 female university science students in 27 classes	✓	Attitude	Very large increases in learning environment scores for an innovative course
Ogbuehi and Fraser (2007)	California, USA	English	661 middle-school mathematics students	✓	Two attitude scales	Used 3 WIHIC & 3 CLES scales Innovative teaching strategies promoted task orientation.

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Taylor and Fraser (2013)	California USA	English	745 high-school students	✓	Mathematics Anxiety	Females were more anxious than males regarding testing of mathematical concepts, but males were more anxious than females regarding the learning of mathematics
Wolf and Fraser (2008)	New York, USA	English	1,434 middle-school science students in 71 classes	✓	Attitudes Achievement	Inquiry-based laboratory activities promoted cohesiveness and were differentially effective for males and females.
Pickett and Fraser (2009)	Florida, USA	English	573 grade 3–5 students	✓	NA	Mentoring program for beginning teachers was evaluated in terms of changes in learning environment in teachers' school classrooms.
Allen and Fraser (2007)	Florida, USA	English Spanish	120 parents and 520 grade 4 and 5 students	✓	Attitudes Achievement	Involved both parents and students Actual–preferred differences were larger for parents than students.
Robinson and Fraser (2013)	Florida, USA	English Spanish	78 parents and 172 kindergarten science students	✓	Achievement Attitudes	Kindergarten level Involved parents Spanish translation Relative to students, parents perceived a more favorable environment but preferred a less favorable environment.
Helding and Fraser (2013)	Florida, USA	English Spanish	924 students in 38 grade 8 and 10 science classes	✓	Attitudes Achievement	Spanish translation Students of NBC teachers had more favorable classroom environment perceptions.

Based on Fraser (2012)

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2.5.2 Evaluation of Educational Innovations

Classroom learning environment instruments can be useful when evaluating the effectiveness of innovative educational programs because they can provide insight beyond standard achievement goals (Fraser et al., 1987) and can also differentiate between traditional classrooms and those with innovative programs (Rentoul & Fraser, 1979; Tisher & Power, 1978). Nix, Fraser, and Ledbetter (2005) evaluated an innovative science teacher development program based on the Integrated Science Learning Environment model (ISLE). A comparative student version of the CLES (CLES-CS) was able to distinguish between different classes and groups. Students whose science teachers had attended the innovative science teacher development program had more-positive classroom learning environment perceptions when compared to classrooms of other teachers in the same schools who had not.

Lightburn and Fraser (2007) evaluated the use of anthropometric activities in terms of student outcomes and classroom learning environment with a sample of 761 secondary school biology students. Results supported the positive influence of the activities in terms of student attitudes and the classroom learning environment.

Houston, Fraser, and Ledbetter (2008) investigated whether using science kits was associated with a more positive learning environment in terms student satisfaction and cohesiveness with a sample of 588 Grades 3–5 students in Texas. Students were in one of three treatment groups – textbook only, science kits only, and a combination of textbook and science kits. Using science kits was associated with a more positive learning environments; this was also generally supported with qualitative data.

Afari, Aldridge, Fraser, and Khine (2013) explored whether the introduction of games into college-level mathematics classes in the United Arab Emirates (UAE) was effective in terms of improving students' perceptions of the learning environment and their attitudes towards mathematics. A comparison of pretest and posttest scores on the WIHIC suggested that students who had been involved in games had significantly higher Teacher Support and Involvement scores than before they were exposed to the games.

Using the WIHIC with 1474 middle-school physical science students in New York, the effectiveness of inquiry-based laboratory activities was evaluated in terms of classroom learning environment, attitudes, and achievement (Wolf & Fraser, 2008). The WIHIC was used to monitor the success of a mentoring program for beginning elementary-school teachers and their 573 school students in Florida in terms of changes in their classroom learning environment (Pickett & Fraser, 2009). Helding and Fraser (2013) used the WIHIC with 927 Grade 8 and 10 students to evaluate the effectiveness of National Board Certified Teachers in South Florida in terms of their students' perceptions of the learning environment. In Singapore, Khoo and Fraser (2008) used the WIHIC to evaluate computer application courses for 250 adults in terms of the classroom environment as perceived by students. Maor and Fraser (2005) developed the Constructivist Multimedia Learning Environment Survey to evaluate computer-assisted learning among 221 Grade 11 and 12 students. Teh and Fraser (1995) used the Geography Classroom Environment Inventory with 671 high-school geography students to evaluate computer-assisted learning in terms of Gender Equity, Investigation, Innovation, and Resource Adequacy.

Three recent studies in the US employed learning environment criteria in evaluation studies with samples of 367 grade 8 science students from two US states (Long & Fraser, 2015), 1097 grade 7 and 8 science students in New York (Cohn & Fraser, in press) and 322 grade 8–10 students in the USA (Oser & Fraser, 2015). When Long and Fraser evaluated the effectiveness of two alternative middle-school science curriculum sequences – namely, a general science model and a topic-specific model (i.e., physics, chemistry, etc.) – they reported that science was enjoyed more by students following the topic-specific sequence. Also, the general curriculum model was more effective for Hispanic students in terms of task orientation, whereas the two alternative sequences were equally effective for Caucasian students. When Cohn and Fraser compared users and non-users of student response systems, large differences ranging from 1.17 to 2.45 standard deviations in favor of users emerged for various learning environment, attitude, and achievement scales. When Oser and Fraser investigated the effectiveness of virtual laboratories in genetics, they reported no significant differences between instructional groups in terms of learning environment and student outcomes.

2.5.3 Teachers' Attempts to Improve Classroom and School Environments

Action research is undertaken by teachers in order to better understand and improve their classrooms (Lewin, 1946). Teacher–researchers can assess the current classroom learning environment, develop and implement strategies for the purpose of improving the environment, and re-assess the learning environment. In South Africa, Aldridge, Fraser, and Sebela (2004) used the CLES to compare students' preferred learning environment with their perceived environment. Using this feedback, two teachers designed teaching strategies whose implementation was able to improve the level of one of the CLES dimensions in each of their classrooms. Using the WIHIC, Aldridge, Fraser, and Ntuli (2009) also used feedback from learners in South Africa. In-service teachers taking a distance-learning program used feedback to improve their classroom environments. Each of the 31 teachers achieved a varying degree of success.

Using the Inventory of Classroom Environments (ICE), based on the WIHIC, Sinclair and Fraser (2002) used student feedback on perceived and preferred classroom environment in an urban North Texas school. Teachers' participation in action research was evaluated in terms of improvement in classroom environment.

Aldridge, Fraser, Bell and Dorman (2012) developed the Constructivist-Oriented Learning Environment Survey (COLES) to investigate students' perceptions of aspects of the learning environment that could be used by teachers to help them to reflect on what is happening in their classroom as viewed by their students. Feedback was provided to teachers in the form of a circular profile (designed and generated for the purpose of the study) that provided a comparison of scale means for actual and preferred responses. (See Figure 2.2 for an example of a circular profile.) Student feedback from the COLES led to changes by teachers that resulted in improvements in their classroom learning environments as perceived by the students.

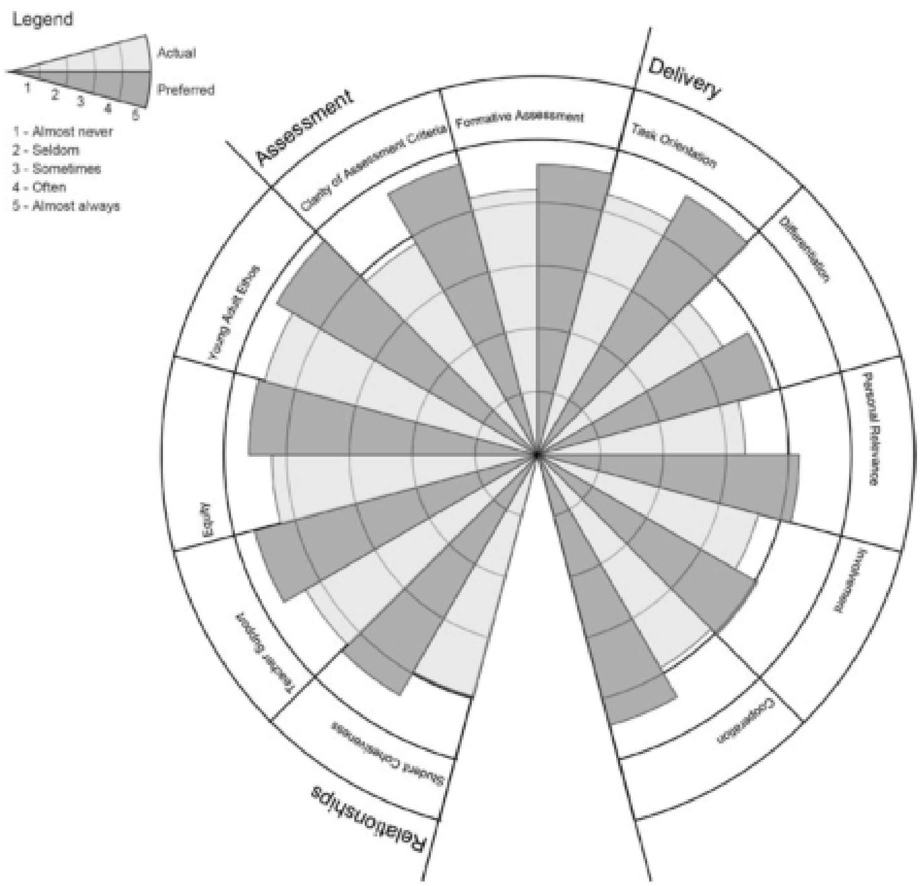

Figure 2.2 Example of Mean Actual and Preferred COLES Scores for Students' Perceptions of the Learning Environment (Aldridge et al., 2012)

2.5.4 Differences between Students' and Teachers' Perceptions of Learning Environment

An investigation of differences between students and their teachers in their perceptions of the same classroom learning environment was reported by Fisher and Fraser (1983) using the ICEQ. Students tended to prefer a more positive environment in terms of the scales measured by the ICEQ than they perceived as being present. In addition, teachers tended to perceive a more positive environment than their students in the same classroom.

Secondary-school students were asked about their perceptions of the behavior of their mathematics and science teachers and the behavior of their best teachers

(Wubbels, 1993). Similarly, teachers were asked about their perceptions of their own behavior and the behavior that they would like to display. On average, teachers did not meet their own ideal and they also differed from the students' perceptions of the best teacher. Using the QTI, Brekelmans, Mainhard, den Brok, and Wubbels (2011) asked teachers of various subjects about their self-perceptions of teacher Control and Affiliation. Similarly, students aged 12 to 18 years were asked about their perceptions of teacher Control and Affiliation. Teachers with a high level of interpersonal competence tended to underestimate their Control and Affiliation, while teachers with a lower level of interpersonal competence tended to overestimate their Control and, especially, Affiliation when compared to their students' perceptions.

2.5.5 Combining Quantitative and Qualitative Methods

Fraser and Tobin have extolled the value of thinking beyond quantitative or qualitative methods and embracing quantitative and qualitative methods (Fraser & Tobin, 1991; Tobin & Fraser, 1998). The inclusion of interpretive data is grounded in the belief "that people know themselves best and can describe, interpret and talk about their own environment" (Anderson & Arsenault, 1998, p. 134).

In Taiwan and Australia, a combination of quantitative and qualitative methods was used to gain understanding of the classroom environments in each country (Aldridge et al., 1999). Quantitative data were gathered through the use of the WIHIC, while qualitative data were gathered through observations and interviews. Even though students in Australia had more favorable perceptions of the classroom environment, students in Taiwan had more positive attitude toward their science class.

Working in Coastal Australia, a team of six researchers investigated two grade 10 science classes over a 10-week period of collecting quantitative and qualitative data (Tobin, Kahle, & Fraser, 1990). The ICEQ and CES were used to collect quantitative data about the students' perceptions of their environment. Other forms of quantitative data included student–teacher interactions, time on task, and documenting social behaviors. Qualitative data included interviews with students and teachers and was found to be consistent with the interpretation of the quantitative data.

2.5.6 School Psychology

Burden and Fraser (1993) investigated the use of the ICEQ as part of British school counselors' assessment tools. The data supported a shift in counselors' focus on academic achievement and other traditional school outcomes to a more holistic approach that also includes the learning environment.

Sink and Spencer (2005) recommend that upper-elementary counselors use a shortened form of the MCI (MCI-SF) to evaluate the efficacy of their programs in terms of improved classroom environment. They found the MCI-SF to be a sound and easy-to-use measurement tool for determining whether counselors' classroom work is fostering a positive learning environment.

2.5.7 Links between Educational Environments

Classroom environments are not isolated, but form part of an ecosystem that consists of the school, parents, and cultural background. For a sample of 37 elementary schools in Maryland, Koth, Bradshaw, and Leaf (2008) found that school-level factors had a smaller influence on students' perceptions of the school environment than did student-level and classroom-level factors. Similarly, Aldridge, Fraser, and Laugksch (2011) reported that, overall, the school environment is not a strong influence on what happens in the classroom based on a sample of secondary schools in South Africa.

In the USA, Fraser and Kahle (2007) used secondary analysis of a large database from a Statewide Systemic Initiative (SSI) to examine the effects of multiple environments on student outcomes. A sample of almost 7000 middle-school science and mathematics students in 392 classes in 200 schools who had participated in the SSI responded to a questionnaire assessing classroom, home, and peer environments as well as student attitudes. All three environments accounted for statistically significant amounts of unique variance in student attitudes.

2.5.8 Cross-National Studies

In a cross-national study in Taiwan and Australia, Aldridge and Fraser (2000) used the WIHIC and reported that, while the quantitative data made an important contribution, qualitative data gave meaning to the comparison. Students from Taiwan and Australia responded to the questions that were meaningful based on their own schema which were influenced by social and cultural factors. Aldridge, Fraser, Taylor, and Chen (2000) also found that qualitative data were helpful in interpreting the quantitative data from the CLES. While some scales (Critical Voice and Student Negotiation) had lower scores in Taiwan and thus suggested a less favorable environment in a Western sense, the scores also reflect the value placed on these constructs in each country.

As with the Taiwan/Australia studies, a cross-national study in Australia and Indonesia (Fraser, Aldridge, & Adolphe, 2010) also revealed cultural differences. For some scales (Involvement and Investigation), Indonesian students perceived their learning environments significantly more positively than did Australian students. However, for other scales (Task Orientation and Equity), Australian students had significantly more positive perceptions of their classroom environments.

2.5.9 Transitions between Different Levels of Schooling

When students move from elementary school to junior high school, the classroom environment can change significantly (Feldlaufer, Midgley & Eccles, 1988). In a longitudinal study of 1040 students from 47 feeder primary and 16 linked secondary schools in Tasmania, the MCI and QTI were used to identify changes in students' perception of the learning environment. It was found the classroom climate was perceived more favorably in secondary schools than in primary schools, whereas the quality of student–teacher interactions was perceived more favorably in primary schools than in secondary schools (Ferguson & Fraser, 1998). This study identified both positive and negative changes in learning environment perceptions during the transition from primary to secondary school, but these changes varied with student gender and the size of the primary school.

2.5.10 Typologies Classroom Environments

Moos (1978) assessed nine dimensions of the social environments among 200 junior-high and high-school classrooms using the CES. Scores on these nine scales were analyzed to yield five distinct orientations of classes: Control oriented, Innovation oriented, Affiliation (structured and unstructured), Task (structured and unstructured), and Competition (structured and unstructured, and Student affiliation). Each cluster showed differences in student and teacher satisfaction.

In the Netherlands and the USA, Brekelmans, Levy, and Rodriguez (1993) used the QTI to identify eight interpersonal clusters: Directive, Authoritative, Tolerant–Authoritative, Tolerant, Uncertain–Tolerant, Uncertain–Aggressive, Repressive, and Drudging. Also using the QTI, Rickards, den Brok, and Fisher (2005), found the same eight clusters for an Australian sample. However, several profiles were found to be less common in the Australian context, while two new ones (Flexible and Cooperative–Supportive) were found in the Australian context.

Applying cluster analysis to data from the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) with an Australian sample of 4146 students, a classroom typology of five groups of classes was identified (Dorman, Aldridge, & Fraser, 2006). These five groups were identified as safe and conservative, non-technological teacher-centered, contested technological, exemplary, and contested non-technological.

Because my study investigated students' attitudes toward science and their understanding of the nature of science as outcomes associated with students' perceptions of the classroom learning environment, the following sections review literature related to attitudes to science (Section 2.6) and nature of science (Section 2.7).

2.6 Assessment of Attitudes toward Science

Because students' attitudes are an important factor in determining student success (Bennett, 2001), the study of students' attitudes towards studying science have received much attention in the science education research community for over 40 years (Tytler & Osborne, 2012). Although students are still interested in science, typically, there is declining interest in school science and a disinterest in science careers (Blalock et al., 2008).

According to Gardner (1975, 1995), there are two broad categories of 'attitude': *attitudes toward science* and *scientific attitudes*. In some sense, attitudes towards science involve how individuals *feel* about science. These attitudes are variables such as relevance, value, and enjoyment. Scientific attitudes refer to qualities that an individual has that are generally considered desirable in a good scientist. These attitudes are variables such as empiricism, skepticism, and determinism. A further distinction involves identifying an object to have feelings about (attitudes toward science) as opposed to a way of thinking (scientific attitude).

2.6.1 Attitudes toward Science

A significant hurdle that must be overcome is the meaning of 'attitudes toward science' as part of the affective domain. Klopfer (1976) delineated "the phenomena toward which some affective behavior by the student is sought or hoped for in science education" (p. 301). These were grouped into four divisions – events in the natural world, activities, science, and inquiry. As students pass through each of the divisions, more formal structured attention is required by the student.

The problem of meaning is further compounded by the understanding that attitude toward science is a multifaceted concept (Tytler & Osborne, 2012) that includes overlapping concepts of attitudes towards science and scientists; attitudes towards school science; enjoyment of science learning; interest in science and science-related activities; and interest in pursuing a career in science. Of particular interest in my study were attitudes towards science and scientists in terms of the Social Implications of Science and Normality of Scientists. Just as there is a variety of instruments to study the learning environment, there are several questionnaires available to study attitudes towards science; some of these instruments are reviewed below.

2.6.2 Attitudes Towards Science Inventory (ATSI)

The ATSI was developed to assess attitudes toward science (Gogolin & Swartz, 1992) by modifying the Mathematics Attitude Inventory that was developed by Sandman (1973) to assess attitudes towards mathematics. The ATSI is a 48-item Likert-type instrument of six scales with eight items per scales: perceptions of the science teacher, anxiety toward science, value of science in society, self-concept in science, enjoyment of science, and motivation science. Content validity was reported for the mathematics version (Sandman, 1973) and construct validity was reported by Gogolin and Swartz (1992) and Weinburgh (1994).

In a study examining teachers' feelings of preparedness to teach about ocean literacy and their attitudes toward ocean science, Eidietis and Jewkes (2011) modified the ATSI by changing the word 'science' to 'ocean science'. Findings indicated that feelings of preparedness and attitude toward ocean science predicted the frequency of teaching about ocean literacy.

2.6.3 Upper Secondary Attitudes Questionnaire

The Upper Secondary Attitudes Questionnaire was developed for investigating the affective components of science teaching goals of the 1980s. During this time, the United States was one of 24 nations participating in the International Association for the Evaluation of Educational Achievement (IEA) Second International Science Study (SISS) project (Menis, 1989). This 28-item Likert-type questionnaire has three levels of agreement: agree, disagree, and uncertain. The 28 items are distributed unevenly across four scales with five to ten items per scale – attitudes toward science (five items), importance of science (ten items), careers in science (six items), and science in school (seven items). Face and content validity were claimed based on an evaluation of the questionnaires by representatives of various nations. The reliability of the questionnaire (KR-20) was reported as being 0.82.

When using three subscales of this instrument (importance of science, science as a career, and science in school) in Northern Ireland, Francis and Greer (1999) found that gender, age, and religion were related to attitudes toward science. Fifth-form girls and students in Catholic schools had less positive attitudes toward school science and science as a career than did boys, third formers, and students in Protestant schools.

In New Zealand, the ATSI was used with high-achieving Year 13 students from rural and low-decile (in terms of social economic status) schools who were participating in the Otago University Advanced School Sciences Academy (OUASSA) project (K. W. Lai, 2013). Students were administered the questionnaire while they resided at the university for five days in January and five days in July. Composite scores indicated that students had positive attitudes toward science.

2.6.4 Test of Science Related Attitudes (TOSRA)

In the 1970s, using the work of Klopfer (1971), Fraser (1977) developed five attitude scales for science teaching: Social Implications of Science; Attitude Toward Inquiry; Adoption of Scientific Attitudes; Enjoyment of Science Lessons; and Interest in Science Outside Lessons. The Social Implications of Science scale is a modified version of the scale developed by Ormerod (1971). The second scale, Attitude Toward Inquiry, is based on a subscale of Meyer's (1969) A Test of Interests. The third scale, Adoption of Scientific Attitudes, is a modified version of the Tests of Perceptions of Scientists and Self, developed by White and Mackay (1976). The final two scales (Enjoyment of Science Lessons, Interest in Science Outside Lessons) are adapted from the Schools Council Project for Evaluation of Science Teaching Methods (Fraser, 1977).

The instrument was improved and extended to form the Test of Science Related Attitudes (Fraser, 1978). The addition of the Normality of Scientists and Career Interest in Science took the number of scales from five to seven. Additional changes to the original five scales included improvement in uniformity of administration directions, response format, and number of items per scale.

The TOSRA is designed to measure seven distinct science-related attitudes among secondary school students. There are 70 items in the seven scales of the TOSRA: Social Implications for 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, 1981). It was developed to be used with secondary-school science students (Dalgety, Coll, & Jones, 2003). The TOSRA has been field tested and validated in Australia (Fraser, 1981), the United States (Khalili, 1987; Welch, 2010), Korea (Fraser & Lee, 2009; H. B. Kim et al., 2000), Singapore (Wong & Fraser, 1996) and Indonesia (Fraser, Aldridge, & Adolphe, 2010; Schibeci & Fraser, 1987). In addition, an eight-item scale based on the TOSRA was used to assess student outcomes in terms of enjoyment, interest, and how much they look forward to science classes (Aldridge et al., 2000).

Quek, Wong, and Fraser (2005) modified the TOSRA to form the Questionnaire on Chemistry Related Attitudes (QOCRA) and used it with gifted and non-gifted students in Singapore. Three of the scales – Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, and Enjoyment of Science Lessons – were renamed as Attitude to Scientific Inquiry in Chemistry, Adoption of Scientific Attitudes in Chemistry, and Enjoyment of Chemistry Lessons.

The TOSRA has also been modified to assess students' attitudes about mathematics (Afari et al., 2013; Ogbuehi & Fraser, 2007; Spinner & Fraser, 2005) to create the Test of Mathematics-Related Attitudes (TOMRA). Walker (2006) modified the TOSRA to measure student attitudes to geography using four scales – leisure interest in geography, enjoyment of geographic education, career interest in geography, and interest in place. This instrument was named the Test of Geography Related Attitudes (ToGRA). Richardson and Brouillette (2013) used the ToGRA to investigate the effect of implementing music history workshops on attitudes and student understanding of geographic concepts.

The Test of Spanish-Related Attitudes (TOSRA-L1) (Adamski, Fraser, & Peiro, 2013) has modified versions of two of the seven scales of the TOSRA (Adoption of Scientific Attitudes and Enjoyment of Science Lessons) that are renamed Cultural Attitudes and Enjoyment of Spanish Lessons, respectively. The TOSRA-L1 incorporates rewording of the TOSRA to focus on attitudes toward Spanish, and it was translated into Spanish. The TOSRA was also adapted for use in China to measure students' attitudes toward English. The English Classroom Learning Environment Inventory (ECLEI) is an eight-item scale based on the Enjoyment of Science scale of the TOSRA (Liu & Fraser, 2013).

2.7 Assessment of Understanding of Nature of Science (NOS)

Although science education literature and organizations state that nature of science is "a major, if not *the* major, goal in science education" (Alters, 1997, p. 39), it is often not explicitly taught. According to Noll (1935), teachers of science have believed that instruction in science leads to developing what he calls *the scientific attitude*. (Noll explains that this scientific attitude is based on habits of thinking that we call understanding of nature of science.) This belief is still prevalent and the nature of science does not usually appear as a topic in science course syllabi (Martin-Dunlop & Hodum, 2009).

A significant hurdle to overcome when discussing the nature of science is clarifying the meaning of 'nature of science' and specifically what it means to different disciplines. In some cases, different scientists (i.e., biologist, chemist, and physicist) could view statements differently. In addition, there can be differences between scientists, science educators, and philosophers of science (Doran et al., 1974). Based on the work of Lederman (1983), Giddings (1982), Cleminson (1990), Aikenhead and Ryan (1992), and the American Association for the Advancement of Science (1993), Alters (1997) identified 39 tenets of NOS in the science education literature, including: characteristics that have reached consensus (Giddings, 1982), science is observation oriented (Cleminson, 1990), science is a human endeavor (Aikenhead & Ryan, 1992), and science is dependent on culture (AAAS, 1993).

Of particular interest in my study was students' understanding of nature of science in terms of the Tentative Nature of Science and the Scientific Method. Just as there is a variety of instruments for studying the learning environment and attitudes towards science, there are also several available questionnaires for assessing students' understanding of nature of science (NOS). An instrument for assessing students' understanding of NOS should have four characteristics (using Noll's interpretation of *scientific attitudes*):

1. Preparation based upon specification of the particular attitude to be assessed.
2. Use of several items to assess each attitude.
3. Provision for the respondent to indicate the extent of his acceptance or rejection of an attitude statement.

4. Concern with intellectual and emotional scientific attitudes (Moore & Sutman, 1970).

2.7.1 Understanding Nature of Science (NOS)

The Test on Understanding Science (TOUS) was developed in 1961 by generating a pool of about 200 multiple-choice items. These were revised and reduced to 120 items that were distributed at several institutions to consultants whose input contributed to more revisions. The TOUS was then administered to a group of 900 high-school students and two smaller groups of high-school students; after each administration, the instrument was further edited into a 60-item instrument with four alternatives per item.

The instrument measures three major areas: understanding about the scientific enterprise, understanding about scientists, and understanding about the methods and aims of science. All items have four choices including a correct response. A sample item in the methods and aims area is:

> Which one of the following statements best describes the most important way that scientists contribute to our society?
> *A.* They provide knowledge about nature. (correct response)
> *B.* They make improved products for better living.
> *C.* They provide skilled services or advice to others.
> *D.* They show us what we should strive for.

The TOUS was used to evaluate the effectiveness of the History of Science Cases for High School instructional method (Cooley & Klopfer, 1963). The case studies were to be used as units within existing high-school courses (Klopfer & Cooley, 1963). Using the TOUS, Mackay (1971) evaluated changes in understanding of NOS of students between grades 7 to 10 and found a number of deficiencies. However, Schmidt (1967) notes that working scientists in Iowa scored more highly than science teachers and students, but their mean score was still almost ten points below the maximum, suggesting that a respectable score on the TOUS is less than was previously thought.

Like the TOUS, the Views on Science-Technology-Society (VOSTS) questionnaire is also a multiple-choice instrument. The authors consider that it is an inventory of students' viewpoints about science. It consists of a pool of 114 items (Aikenhead, Ryan, & Fleming, 1989) which were developed to avoid the assumption that the researcher and student would interpret items in the same way (Aikenhead, 1988). The items were developed over a six-year period through a five-step process with upper-secondary students in Canada (Aikenhead & Ryan, 1992). The steps started with students responding to items using a three-point Likert scale (agree, disagree, cannot tell) and writing a paragraph justifying their choice; then the evaluator analyzed student responses to find common student positions and, in the third step, another group of students responded to revised statements by writing a paragraph, choosing one of the student position statements, and participating in an interview with the evaluator, resulting in another revision. In the fourth step, another group of students went through the revised VOSTS, talking about the choices that they made; when a final sample of students responded to the VOSTS, items with no response and uninteresting feedback were eliminated.

Two instruments used in my study were the Scientific Attitude Inventory: Revision (SAI-II) and the Views on Science and Education Questionnaire (VOSE). The original Scientific Attitude Inventory (SAI) and the VOSE were developed to investigate understanding of nature of science with different students at different levels of education. The SAI was developed in response to a need for a single instrument to assess understanding of nature of science at the high-school level (Moore & Sutman, 1970). The VOSE was developed to create in-depth profiles about the views of college students regarding the nature of science and science instruction using a valid, meaningful, and practical instrument (S. Chen, 2006b). The SAI-II and VOSE are discussed further below in Sections 2.7.2 and 2.7.3.

2.7.2 Scientific Attitude Inventory–Revision (SAI-II)

The SAI contains 12 position statements, six positive and six negative. The statements are also categorized as intellectual or emotional attitudes, again with six statements for each. The six position statements are Tentative Nature of Science, Empirical Basis of Science, Scientific Method, Science as an Idea-Generating Activity, Necessity for Public Support of Science, and Personal Attributes Necessary for a Career in Science. The SAI-II is a revised version of the original SAI in response to criticism about "…vocabulary, item difficulty, and format…" (Moore & Foy, 1997, p. 329). The revision focused on three goals: eliminating gender-biased references; eliminating words that could be too difficult; and shortening the instrument. In the process, the original 12 position statements were maintained and no new ones were added.

There are 40 five-point Likert-type attitude statements in the six position statements of the SAI-II. While the instrument is called the Scientific Attitude Inventory II, the statements of the inventory are consistent with Lederman's conception of NOS:

> Although the “nature of science” has been defined in numerous ways, it most commonly refers to the values and assumptions inherent to the development of scientific knowledge For example, an individual’s beliefs concerning whether or not scientific knowledge is amoral, tentative, empirically based, a product of human creativity, or parsimonious reflect that individual’s conception of the nature of science. (Lederman & Zeidler, 1987, p. 721)

The validity claimed for the SAI-II is based on content validation of the SAI, which involved selecting items on the basis of data obtained from high-school students and a panel of judges that “consisted of 4 science educators, 4 practicing scientists, and 2 liberal arts science professors” (Moore & Foy, 1997, p. 328). Items selected received the greatest support from the panel of judges *and* were not unanimously endorsed or rejected by the students (Moore & Sutman, 1970). Construct validity of the SAI-II was also claimed based on the demonstrated validity of the SAI in the original field test. Psychometric validity is often not reported for nature of science instruments because researchers might view items as only being open to one interpretation and therefore do not requiring validation (Tytler & Osborne, 2012). This position is supported by Nadelson and Viskupic (2010) who assert that some groups of respondents might interpret items in the same way as the researcher.

For a sample of 557 Grade 6, 9, and 12 rural/suburban students, Moore and Foy (1997) reported that the SAI-II had a Cronbach alpha coefficient of 0.781 for the whole instrument, but they provided no factor analysis results to support the instrument’s scale structure. However, the SAI-II was able to distinguish between the responses of the upper 27% and lower 27% of respondents on the instrument’s total score.

Demirbaş and Yağbasan (2006) used a Turkish translation of the SAI-II with a sample of 300 middle-school students and reported a Cronbach alpha coefficient of 0.76. When used in a study with a sample of 94 Grade 7 students, a Thai version of the SAI-II was found to have an alpha coefficient of 0.81 (Cojorn, Koocharoenpisal, Haemaprasith, & Siripankaew, 2013). In New Mexico, a modified SAI-II was used with a sample of 95 middle-school students, 88% of whom self-identified as Hispanic (Sorge, Newsom, & Hagerty, 2000), and was found to have an alpha coefficient of 0.734.

In the USA, the SAI-II was found to have an alpha coefficient of 0.78 when used in a study with a sample of 117 Grade 11 students (Liang, 2002). In the Boston Public Schools, a modified version of the SAI-II was used over a two-year period with secondary science students (Barnett et al., 2006) and found to have scale reliabilities ranging from 0.67 to 0.85.

At the post-secondary level in the USA, when Nadelson and Viskupic (2010) used the SAI-II with a sample of 61 lower- and upper-division geoscience students, they reported a Cronbach alpha coefficient of 0.83. In another study with 89 preservice teachers from two universities (Nadelson & Sinatra, 2010), an alpha coefficient of 0.79 was reported.

Demirbaş (2009) also found an alpha coefficient of 0.72 when the SAI-II was piloted with a sample of 100 Turkish science teachers. Another Turkish study with preservice elementary teachers (Cavas, Ozdem, Cavas, Cakiroglu, & Ertepinar, 2013) reported that the SAI-II had an alpha reliability coefficient of 0.72. A version of the SAI-II modified for the Indian context was used in a study of 300 preservice teachers from four teacher training colleges and was found to have an alpha reliability of 0.927 (Lahiri, 2011).

It is worth noting that in all but one (Barnett et al., 2006) of the above ten studies, the Cronbach alpha coefficient is reported for the total score and not for individual scales. In addition, factor structure was not reported for any of these studies. Therefore, my study is distinctive because it provided evidence for the factorial validity of NOS scales, as well as for the reliability of each individual NOS scale.

2.7.3 Views on Science and Education Questionnaire (VOSE)

The VOSE was developed in response to a need for an instrument that addressed the difficulty in administering NOS instruments to large samples. After the late 1980s, NOS studies typically used a more qualitative approach. These instruments were open-ended, resulting in two particular types if difficulties – participants finding it challenging to completely and accurately articulate their NOS beliefs; and researchers spending considerable time in obtaining the intended information from participants (S. Chen, 2006a). The VOSE is based on the Views on Science-Technology-Society (VOSTS) developed in Canada over a six-year period (Aikenhead & Ryan, 1992). However, the VOSTS was developed in response to the identification of an erroneous assumption on the part of researchers – that students and researchers perceive the same meaning (Aikenhead, 1988). The researchers developed a pool of 114 items "that capture students' reasoned viewpoints on STS (Science-Technology-Society) topics, and does so with greater clarity than paragraph responses, and with much greater clarity than Likert-type responses" (Aikenhead & Ryan, 1992, p. 488).

The VOSE contains 15 questions followed by several items representing various philosophical positions, totaling 85 statements (S. Chen, 2006b). There are 10 questions addressing seven aspects of NOS and five questions covering the teaching attitudes corresponding to five of the NOS aspects. The seven aspects are: Tentativeness of Scientific Knowledge; Nature of Observation; Scientific Methods; Hypotheses, Laws, and Theories; Imagination; Validation of Scientific Knowledge; and Objectivity and Subjectivity in Science. The five teaching attitudes correspond to the five nature of science topics of Tentativeness of Scientific Knowledge; Nature of Observation; Scientific Methods; Hypotheses, Laws, and Theories; and Objectivity and Subjectivity in Science.

The 85 five-point Likert-type statements align with Lederman's conception of nature of science (Lederman & Zeidler, 1987). Although the VOSE was designed for college students, 10th to 12th grade students could also find it appropriate because it uses language similar to the VOSTS, which was designed for high-school students (S. Chen, 2006b).

Content validity is claimed for the VOSE based on reviews by two panels of experts, who also examined the philosophical meaning of each item. In addition, seven student interviews provided information about content clarity and revealed that, for 83 of the 85 items, the interpretation was 90% similar for respondent and researcher.

Finally, a final test, a retest, interviews, and data analysis established validity and reliability (S. Chen, 2006a).

Based on the ideas of Aikenhead and Ryan (1992) and Rubba, Harkness, and Bradford (1996) that conventional concepts of validity and reliability cannot apply to empirically-developed instruments, Chen (2006a) focused on the quality and meaningfulness of the items rather than pursuing high internal consistency. The reliability of each scale was expected to be within a range of reasonable values, but was not a main criterion for item selection. Cronbach's alpha was used to identify items to be discarded during the pilot test.

The VOSE was administered to 302 junior and senior students majoring in biology, life science, chemistry, physics, foreign languages and literature, and Chinese literature at two research universities in Taiwan. Twenty-four participants completed the questionnaire again within 1 to 3 months for test-retest reliability. In addition, these participants were interviewed following the retest. The test–retest coefficient of 0.82 is satisfactory considering the small sample size (n=24) and the relatively long duration between test and retest (1–3 months). The Cronbach alpha coefficient for the different scales ranged from 0.34 to 0.80.

The VOSE was administered to 17 secondary science teachers in six public schools in a rural school district in the United States as part of the evaluation of the effectiveness of a professional development activity (Burton, 2013). While reliability and validity were not reported, a statistically significant difference between the pretest and posttest responses was reported for items representing Scientific Methods,

$t(1,16) = 6.67$, $p < 0.001$, Theories and Laws, $t(1,16) = 5.00$, $p < 0.001$, and Subjectivity and Objectivity, $t(1,16) = 5.15$, $p < 0.001$. In addition, scores for the scales of Tentativeness, Nature of Observations, and Use of Imagination were not found to change statistically significantly different between pretest to posttest. Items representing the Validation of Scientific Knowledge had scores of below 2.0 on a 0–4 scale.

In quantitatively examining the extent to which the understanding levels of NOS and the quality of argumentation correlate, Lai (2012) used a mixed-method approach that included the VOSE. Participants were 57 third-year biology majors enrolled in a second-semester evolution course in Taiwan. Lai reported that, for the Class of 2010 ($n = 24$), the highest score on the VOSE questionnaire was 178, the lowest score was 133, and the mean score was 155.76 ($SD = 11.907$). While Cronbach's alpha coefficient was not reported, it was used to remove items that detracted from the reliability. Items 14 and 15 were not included in the calculation of total scores. For the Class of 2011 ($n = 32$), the highest score was 169, the lowest score was 140, and the mean score was 153.78 ($SD = 8.031$).

In a study with 63 secondary biology students in the Midwest USA, Smith (2010) examined the use of short stories to improve students' understanding of nature of science. The control group used the textbook, while the treatment group read short stories about scientists (Mendel and Darwin). She used the Views on Science Questionnaire 1 and 2 (VSQ1 and VSQ2, respectively) to assess students' understanding of nature of science. VSQ1 consists of a subset of VOSE items, while VSQ2 comprises VOSE-like questions. Cronbach's alpha coefficients were reported as ranging from 0.266 to 0.875 for VSQ1 items in the initial analysis. Further statistical analysis using MANCOVA revealed significant differences between the control and treatment groups for both the combined VSQ1 components (F (4,52) = 3.803, p = 0.009, Wilks' Lambda = 0.774, partial eta squared= 0.226) and the combined VSQ2 items (F (3, 54) = 3.398, p = 0.024, Wilks' Lambda = 0.841, partial eta squared = 0.159). No significant differences between control or treatment group existed for the combined non-explicit VSQ1 components (F (3, 54) = 0.867, p=0.464, Wilks' Lambda= 0.945, eta squared= 0.046).

With a sample of 700 preservice science teachers in West Bengal India, Mukhopadhyay (2013) examined the correlation between teaching competence and understanding of nature of science. Using the correlation of teachers' competence in teaching science with each of the other selected variables (nature of science) he reported that teaching competence in science was significantly correlated with understanding of nature of science. In addition, a multiple regression model predicted 57.76% of variance in scores of competence in teaching. Stepwise regression analyses showed that a major percentage of the variance was explained by some of the nature of science variables; with this result, he reported that teachers' understanding of nature of science significantly predicted their teaching competence.

Past studies support associations between the classroom learning environment and various student outcomes. Of particular interest in my study were the outcomes of student attitudes to science and student understanding of nature of science; therefore I chose to use a modified version the TOSRA and SAI-II/VOSE in my research.

2.8 Chapter Summary

This chapter provided a review of the literature relevant to this study. Section 2.2 reviewed the historical context of learning environments research, beginning with the work of Lewin (1936a) and Murray (1938), both of whom recognized and identified the existence of a relationship between a person and his or her environment. In the 1960s and 1970s, work by Moos (1974) and Walberg (Walberg & Anderson, 1968) led to research specifically on classroom learning environments. Factors that affect classroom learning environment and educational productivity include demographic characteristics such as gender race and age; educational characteristics such as cognitive complexity and interpersonal the maturity; and the individual's traits, values, and modes of functioning.

Section 2.3 reviewed numerous instruments that are available to assess the learning environment, including the Learning Environment Inventory (LEI), the Classroom Environment Scale (CES), the Individualized Classroom Environment Questionnaire (ICEQ), the College and University Classroom Environment Inventory (CUCEI), the My Class Inventory (MCI), the Questionnaire on Teacher Interaction (QTI), the Science Laboratory Environment Inventory (SLEI), and the Constructivist Learning Environment Survey (CLES), Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI), and Constructivist-Oriented Learning Environment Survey (COLES).

The next section specifically focused on the What Is Happening In this Class? (WIHIC) instrument because it was used in my study. Reviewed were the psychometric properties of the WIHIC and various studies that have used the WIHIC internationally. Overall, these studies have shown the WIHIC to be valid, reliable and useful in a variety of classrooms.

Section 2.5 focused on specific research areas within the field of learning environments, such as associations between student outcomes and environment; evaluation of educational innovations; teachers attempts to improve classroom and school environments; differences between students' and teachers' perceptions of the environment; use of quantitative and qualitative methods; school psychology; links between educational environments; cross-national studies; transition between different levels of schooling; and typologies of classroom environments.

Section 2.6 focused on student attitudes toward science and reviewed questionnaires such as the Attitudes Toward Science Inventory (ATSI), the Upper Secondary Attitudes Questionnaire, and the Test of Science Related Attitudes (TOSRA). The TOSRA, specifically, was designed to measure seven distinct science-related attitudes among secondary school students. It has been adapted for and used in a variety of situations, has been found to be valid and reliable, and was selected for inclusion in my study.

Section 2.7 focused on student understanding of nature of science, including reviewing the Test of Understanding Science (TOUS) and the Views on Science-Technology-Society (VOSTS). The Scientific Attitude Inventory-Revision (SAI-II) and the Views on Science and Education (VOSE) were used to assess understanding of Nature of Science (NOS) in my study. For the VOSE and SAI, content and construct validity have been based on input from experts and students.

The next chapter describes research methodology used in this study. Included is information about the research objectives, the design of the study, the sample, the instruments used, and the methods of data collection and analysis.

Chapter 3

METHODOLOGY

3.1 Introduction

The previous chapter provided a review of literature relevant to this study; this chapter describes and justifies the methods used in my research. The chapter includes descriptions of the development of the questionnaire scales, the sample, and the procedures for collecting and analyzing the data. This chapter includes the following sections:

- Research Objectives (3.2)
- Development of the Questionnaire (3.3)
- Sample (3.4)
- Data Collection (3.5)
- Data Analyses (3.6)
- Chapter Summary (3.7).

3.2 Research Objectives

As previously identified, the two main research objectives of this study were:

- To validate scales based on the What Is Happening In this Class? (WIHIC), Test of Science Related Attitudes (TOSRA), and Scientific Attitude Inventory – Revision/Views on Science and Education (SAI-II/VOSE) with students in a suburban secondary school with urban demographics in mid-western USA.

- Identify characteristics of the science classroom environment that enhance students' attitudes to science and understanding of nature of science.

After reviewing literature about various questionnaires available, scales from four questionnaires were selected to measure students' perceptions of the classroom learning environment, attitudes towards science, and understanding of nature of science. To measure perceptions of the learning environment, four scales from the What Is Happening In this Class? (WIHIC) were selected. To measure attitudes towards science, two scales from the Test Of Science Related Attitudes (TOSRA) were selected. Finally, to measure understanding of nature of science, three scales were selected from the Scientific Attitude Inventory Revision (SAI-II) and Views on Science and Education (VOSE).

Based on convenience and practical considerations when administering the scales, the four learning environment scales, two attitude scales, and three nature of science scales were assembled into one questionnaire with a single response format. Prior to using the questionnaire for investigating the second research question in the study, the questionnaire had to be validated, which addressed my first research question. After validating the questionnaire, associations between the classroom learning environment and attitudes and understanding of nature of science were investigated (my second research question).

3.3 Development of the Questionnaire

Instead of using four questionnaires (one each for the classroom learning environment, attitudes to science, and two for understanding of nature of science) or creating an entirely new questionnaire, scales from four established instruments were modified and assembled into one – What Is Happening In this Class? (WIHIC), Test of Science Related Attitudes (TOSRA), Scientific Attitudes Inventory Revision (SAI-II), and Views on Science and Education (VOSE). Four scales were chosen from the WIHIC (learning environment), two scales were chosen from the TOSRA (attitude to science), and two scales were chosen from the SAI-II and VOSE (understanding of nature of science).

The modification and combination of scales from four established instruments into one was designed to reduced students' reluctance to thoughtfully complete multiple or long questionnaires. The original frequency response format of the WIHIC was changed to the same Likert-type response of the TOSRA and SAI-II – Strongly Agree, Agree, Uncertain, Strongly Disagree, and Disagree. This avoided confusing students and maintained consistency throughout the questionnaire. In addition, the same instructions were used for all scales throughout the questionnaire and placed at the top of every page – "Please select the **one** choice that best describes your response." Another modification was the use of the common stem "In this science class…" This was placed below each scale label.

3.3.1 Learning Environment Scales

The WIHIC was used in this study to assess students' perceptions of the classroom learning environment because it combines scales from previous instruments and includes contemporary dimensions such as constructivism and equity. There are 56 items in the seven original scales of the WIHIC: Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, and Equity. Of the seven scales of the WIHIC, four were chosen as being most salient for my study – Involvement, Investigation, Cooperation, and Task Orientation. The Involvement scale measures the extent to which students have attentive interest, participate in discussions, do additional work and enjoy the class. The Investigation scale measures the extent to which skills and processes of inquiry and their use in problem solving and investigation are emphasized. The Cooperation scale measures the extent to which students cooperate rather than compete with one another on learning tasks. The Task Orientation scale measures the extent to which it is important to complete activities planned and to stay on the subject matter.

A review of the literature (see Section 2.4) shows the WIHIC has been found to be valid and reliable when used with 978 high-school students in Australia (Dorman, 2008); 1404 high-school students in Australia and Canada (Zandvliet & Fraser, 2005); 1161 high-school students in Indonesia and Australia (Fraser, Aldridge, & Adolphe, 2010); 543 Korean high-school students (H. B. Kim et al., 2000); 1021 high-school students in India (Koul & Fisher, 2005); 250 adults in Singapore (Khoo & Fraser, 2008); 2310 Singaporean high-school students in geography and mathematics (Chionh & Fraser, 2009); 113 middle-school students in Taiwan (Yang et al., 2012); 665 middle-school students in the USA (den Brok et al., 2006); 661

students in the USA (Ogbuehi & Fraser, 2007); 520 elementary students in the USA (Allen & Fraser, 2007); and 525 preservice elementary teachers in the USA (Martin-Dunlop & Fraser, 2008).

The number of items in, a description of, and a sample item for each of the four scales used in my study are given in Table 3.1. In the context of the study, Involvement measured the extent to which students perceived that they shared and communicated ideas; Investigation measured the extent to which students perceived that they engaged in problem solving; Cooperation measured the extent to which students perceived that they worked with others; and Task Orientation measured the extent to which students perceived that they knew the goals of the class and focused on them.

Table 3.1 Description of Scales and a Sample Item for Each WIHIC Scale

Scale	No of Items	Description of Scale	Sample Item
Involvement	8	The extent to which students have attentive interest, participate in discussions, do additional work and enjoy the class	I discuss ideas in class.
Investigation	8	The extent to which skills and processes of inquiry and their use in problem solving and investigation are emphasized	I carry out investigations to test my ideas.
Cooperation	8	The extent to which students cooperate rather than compete with one another on learning tasks	I learn from other students in this class.
Task Orientation	8[a]	The extent to which it is important to complete activities planned and to stay on the subject matter	I know the goals for this class.

Based on Dorman (2003)
[a] One item (number 4) was omitted after the data analysis described in Chapter 4.

The four learning environment scales in Table 3.1 were selected for my study for three main reasons. First, the scales have consistently exhibited strong validity and reliability in the considerable past international research reviewed above. Second, of the seven WIHIC scales, these four scales were most salient for my specific study and research questions. Third, the constructs assessed by these four WIHIC scales are relevant to the standards for science that have been adopted in the US state (namely, Illinois) where my study was undertaken.

The standards adopted in Illinois are *A framework for K–12 science education* (National Research Council, 2012) and the *Next Generation Science Standards* (NGSS Lead States, 2013). Table 3.2 provides, for each learning environment scale in my study, a scale description and a quote from one of the two standards documents that demonstrates the relevance of each learning environment construct to the standards. Overall, Table 3.2 helps to justify my choice of learning environment scales in terms of their consistency with prevailing science standards.

3.3.2 Attitude to Science Scales

Whereas Section 3.3.1 described the scales used to assess the learning environment in my research, the current section considers the scales that I used for assessing students' attitudes to science. Fraser (1978) developed the TOSRA to measure separate affective aims for science education. In the 1970s, using the work of Klopfer (1971), Fraser selected five attitude scales for science teaching: Social Implications of Science; Attitude Toward Inquiry; Adoption of Scientific Attitudes; Enjoyment of Science Lessons; and Interest in Science Outside Lessons (1977). Two more scales –

Normality of Scientists and Career Interest in Science – were added making a total of 70 items in seven scales (Fraser, 1978).

A review of the literature (see Section 2.6.4) shows the TOSRA has been found to be valid and reliable when used with 543 secondary-school students in Korea (H. B. Kim et al., 2000); 439 senior high-school students in Korea (Fraser & Lee, 2009); 752 secondary-school students in Indonesia (Schibeci & Fraser, 1987); 1161 Grade 9 and students in Indonesia and Australia (Fraser, Aldridge, & Adolphe, 2010); 1879 high-school students in Taiwan and Australia (Aldridge et al., 2000); 352 mathematics students in the United Arab Emirates (Afari et al., 2013); 497 secondary students in Singapore (Quek et al., 2005); 1592 secondary-school chemistry students in Singapore (Wong & Fraser, 1996); 3526 secondary-school students from Pakistan (Anwer, Iqbal, & Harrison, 2012); 311 middle-school students in the USA (C. H. Chen & Howard, 2010); 2961 middle school students in Turkey (Hacieminoglu, Yilmaz-Tuzun, & Ertepinar, 2011); 132 high-school students in the USA (Welch, 2010); and 1434 middle-school students in the USA (Wolf & Fraser, 2008).

Table 3.2 Description of Scales and Their Relevance to K–12 Science Frameworks and Next Generation Science Standards

Scale	Description of Scale	Relevance to K–12 Framework and NGSS
Involvement	The extent to which students have attentive interest, participate in discussions, do additional work and enjoy the class	Students at any grade level should be able to ask questions of each other about the texts they read, the features of the phenomena they observe, and the conclusions they draw from their models or scientific investigations. (NRC, p. 56)
Investigation	The extent to which skills and processes of inquiry and their use in problem solving and investigation are emphasized	Students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller-scale mechanisms within the system. (NGSS Appendix G)
Cooperation	The extent to which students cooperate with one another on learning tasks	Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. (NGSS Appendix F)
Task Orientation	The extent to which it is important to complete activities planned and to stay on the subject matter	Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design decide on types, how much, and accuracy of data needed to produce reliable measurement and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (NGSS Appendix G)
Social Implications of Science	Extent to which students appreciate the value of science	Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risk. (NRC, p. 214)
Normality of Scientists	Extent to which students perceive that scientists look and act like other people	Individuals and teams from many nations and cultures have contributed to science and to advances in engineering. Scientists' backgrounds, theoretical commitments, and fields of endeavor influence the nature of their findings. (NGSS Appendix H)
Tentative Nature of Science	Scientific knowledge is durable and not easily changed. On the other hand, all scientific knowledge is subject to change.	Most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. (NGSS Appendix H)
Scientific Method	There is no universal scientific method. Scientists apply various methods in doing research.	Science investigations use diverse methods and do not always use the same set of procedures to obtain data. Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge. (NGSS Appendix H)

NRC: National Research Council. Committee on a Conceptual Framework for New K–12 Science Education Standards. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

NGSS: NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press.

Two scales of the TOSRA were chosen – Social Implications of Science and Normality of Scientists – consisting of six items each (see Table 3.2). The Social Implications scale measures one aspect of manifestation of favorable attitudes towards science, such as the social benefits and problems that accompany scientific progress. The Normality of Scientists scale measures one aspect of manifestation of favorable attitudes towards scientists, such as an appreciation that scientists are normal people rather than eccentrics as is often depicted in the mass media (Mead & Métraux, 1957).

The number of items in, a description of, and a sample item for each of the two scales used is given in Table 3.3. In the context of the study, Social Implications of Science measured the extent to which students appreciated the value of science. Normality of Scientists measured the extent to which students perceived that scientists look and act like people students know.

Table 3.3 Description of Scales and a Sample Item for Each Scale of the Modified TOSRA

Scale	No of Items	Description of Scale	Sample Item
Social Implications of Science	6	Extent to which students appreciate the value of science	Science helps to make life better.
Normality of Scientists	6	Extent to which students perceive that scientists look and act like other people.	Scientists like sports as much as other people do.

Based on Fraser (1978)

As with learning environment scales, attitude scales were chosen for the same reasons: convincing validity evidences from many past international studies; salience to my study's research questions; and consistency with the standards for science education adopted in Illinois. Table 3.2 provides a quote from these standards documents (National Research Council (NRC). Committee on a Conceptual Framework for New K-12 Science Education Standards, 2012; NGSS Lead States, 2013) in order to demonstrate the consistency of these attitude constructs with the standards and therefore justify their inclusion in my study.

3.3.2 Understanding Nature of Science Scales

Understanding of nature of science scales in my study was assessed by combining items from the Scientific Attitude Inventory-Revision (SAI-II) and the Views on Science and Education (VOSE). The SAI-II was developed by Moore and Sutman (1970) in response to a need for a single instrument to assess understanding of nature of science for the high-school level. The VOSE was developed in response to criticisms regarding the researcher vs. participant interpretation of survey or questionnaire items and the difficulty of administering and analyzing open-ended questions to a large number of participants.

The six scales of the SAI-II are Tentative Nature of Science, Empirical Basis of Science, Scientific Method, Science as an Idea-Generating Activity, Necessity for Public Support of Science, and Personal Attributes Necessary for a Career in Science. The SAI-II is a revised version of the original SAI in response to criticism about gender bias and readability (Moore & Foy, 1997). The inventory has been identified as the most well-known and frequently-used instrument for measuring student understanding of nature of science (Munby, 1997; Osborne, Simon, & Collins, 2003).

A review of the literature (see Section 2.7.2) shows that validity claims for the SAI-II have been based on the original SAI. It has been found to be reliable when used with 557 Grade 6, 9, and 12 rural/suburban students in the USA (Moore & Foy, 1997); 300 middle-school students in Turkey (Demirbaş & Yağbasan, 2006); 100 Turkish science teachers (Demirbaş, 2009); 1072 Turkish preservice elementary teachers (Cavas et al., 2013); 94 Grade 7 students in Thailand (Cojorn et al., 2013); 300 preservice teachers in India (Lahiri, 2011); 117 Grade 11 students in the USA (Liang, 2002); 95 middle-school students in the USA (Sorge et al., 2000); 61 lower- and upper-division geoscience university students in the USA (Nadelson & Viskupic, 2010); and 89 preservice teachers in the USA (Nadelson & Sinatra, 2010). It is noteworthy that factor structure was *not* reported in any of the above studies (and therefore was a priority in my study).

Of the 40 questions in six scales identified by Moore and Sutman (1970) as position statements, I used 11 questions in two scales. The Tentative Nature of Science scale measures understanding that the laws and/or theories of science are approximations of truth and are subject to change. The Scientific Method scale measures the understanding that, to operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one's position on the basis of sufficient evidence.

The VOSE contains 15 questions followed by several items representing various philosophical positions, totaling 85 statements (S. Chen, 2006b). The seven aspects of nature of science are: Tentativeness of Scientific Knowledge; Nature of Observation; Scientific Methods; Hypotheses, Laws, and Theories; Imagination;

Validation of Scientific Knowledge; and Objectivity and Subjectivity in Science. In addition to the seven aspects of NOS, there are five questions covering teaching attitudes corresponding to five of the NOS aspects: Tentativeness of Scientific Knowledge; Nature of Observation; Scientific Methods; Hypotheses, Laws, and Theories; and Objectivity and Subjectivity in Science.

A third scale of the SAI-II and VOSE (Empirical Basis of Science/Objectivity and Subjectivity in Science) was initially included in my study. But, as reported later in Chapter 4, this did not meet statistical criteria for retention, namely, that every item must have a factor loading of at least 0.40 with its own scale and less than 0.40 with all other scales. This scale measures understanding that observation of natural phenomena and experimentation is the basis of scientific explanation, science is limited in that it can only answer questions about natural phenomena, and sometimes it is not able to do that.

A review of the literature (see Section 2.7.3) revealed that a test–retest reliability coefficient of 0.82 was reported for the VOSE when administered to 302 junior and senior students in Taiwan and with a relatively long duration between test and retest (S. Chen, 2006a). When administered to 17 secondary science teachers in the United States, there was a statistically significant difference between the pretest and posttest responses (Burton, 2013). An improvement in understanding of nature of science was found for 57 biology majors in Taiwan (M. C. Lai, 2012) and 63 secondary biology students in the Midwest USA (J. A. R. Smith, 2010). A correlation was reported between understanding of nature of science and teaching competency with 700 preservice science teachers in West Bengal India (Mukhopadhyay, 2013).

The Tentativeness of Science scale measures that, although scientific knowledge is durable and not easily changed, it is also subject to change. The Scientific Method scale measures the understanding that there is no universal scientific method – scientists apply various methods in doing research.

These two scales of the SAI-II and VOSE, namely, Tentative Nature of Science and Scientific Method, were selected because they were the most relevant to my study. In the context of the study, Tentative Nature of Science measured the extent to which students understood that scientific knowledge changes, but not easily, and Scientific Method measured the extent to which students understood that scientific methods depend on careful observations. The number of items in, a description of, and a sample item for each of the two scales used are given in Table 3.4.

These two NOS scales that survived the validity analyses reported later in Chapter 4 are Tentative Nature of Science and Scientific Method. Therefore these two scales are included in Table 3.2 to demonstrate their relevance to the science education standards adopted in Illinois. That is, the selection of these two NOS scales for my study can be justified in part in terms of their consistency with the science education standards.

Table 3.4 Description of Scales and a Sample Item for Each Scale of the Modified SAI-II/VOSE

Scale	No of Items	Description of Scale	Sample Item
Tentative Nature of Science	3	The laws and/or theories of science are approximations to truth and are subject to change	Scientific ideas can be changed. (SAI-II)
Tentative Nature of Science	3	Scientific knowledge is durable and not easily changed. On the other hand, all scientific knowledge is subject to change.	Scientific research will face change and old theories will be replaced. (VOSE)
Empirical Basis of Science	3[a]	Observation of natural phenomena and experimentation are the basis of scientific explanation	Some questions cannot be answered by science. (SAI-II)
Objectivity and Subjectivity in Science	3[a]	Scientific knowledge is empirically based. Scientists try to be open-minded and apply mechanisms such as peer review and data triangulation to improve objectivity. On the other hand, personal beliefs, values, intuition, judgment, creativity, opportunity, and psychology all play a role.	Two theories can provide explanations from different viewpoints. (VOSE)
Scientific Method	3	To operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one's position on the basis of sufficient evidence	Scientific questions are answered by observing things. (SAI-II)
Scientific Method	3[b]	There is no universal scientific method. Scientists apply various methods in doing research.	There is no fixed scientific method. (VOSE)

Based on Moore and Foy (1997) and Chen (2006a)
[a] Empirical Basis of Science scale was omitted after data analysis.
[b] One item (number 6) was omitted.

3.3.3 Questionnaire Used in My Study

The questionnaire used in my study initially consisted of nine scales with six or eight items in each scale. The four classroom learning environment scales each consisted of eight items, while the two attitude and three nature of science scales each consisted of six items, making a total of 62 questions. The questionnaire is provided in Appendix A. The classroom learning environment and attitude scales are taken directly from the WIHIC and TOSRA, respectively. The nature of science scales are a combination of SAI-II and VOSE items. The Tentative Nature of Science scale from the SAI-II is combined with the Tentativeness of Scientific Knowledge scale from the VOSE; the Empirical Basis of Science scale from the SAI-II is combined with the Nature of Observation scale from the VOSE; and the Scientific Method scale from the SAI-II is combined with the Scientific Methods scale from the VOSE. Each nature of science scale has three items from the SAI-II and three from the VOSE. (However, as reported in Chapter 4, one NOS scale was lost during the factor analysis.)

After the selection and modification of the desired scales of the WIHIC, TOSRA, and SAI-II/VOSE, they were combined to create a single questionnaire. So that students were not discouraged by numerous different questionnaires or an overly long questionnaire, a single one was formed. To reduce the length and complexity of the instrument, a single set of instructions was located at the beginning and all questions were scored using the same five-point Likert scale – Strongly Agree (5), Agree (4), Uncertain (3), Strongly Disagree (2), and Disagree (1). (The original WIHIC employs a frequency response scale with alternatives ranging from Almost Never to Almost Always.)

3.4 Sample

The sample consisted of 246 secondary students in a medium-sized, Midwestern, suburban secondary school with urban demographics in the USA. All students were enrolled in a science class in grades 10 to 12. According to the United States Department of Education (Geverdt & Phan, 2006), the school's community is classified as suburban (i.e. a large "territory outside a principal city and inside an urbanized area with population of 250,000 or more”). In addition, the racial and ethnic characteristics of the school are similar to those in large urban districts – African-American and Hispanic students representing a larger percentage of the student population than the White minority (Frankenberg, 2009).

While students were enrolled in a science course, the questionnaire was completed in either their mathematics class or a high-stakes test preparation class. In no case, did a student complete the questionnaire in the presence of his or her science teacher. In addition, students were guaranteed confidentiality and anonymity. Not only were student responses not to be shared with their science teacher, but questionnaires results were not returned to the school.

3.5 Data Collection

A pilot study was completed to check the questionnaire’s readability and administration logistics. A group of 16 students completed a web-based version of the questionnaire. This small group of students, in their third or fourth year of secondary science (grades 11 and 12), checked the readability and comprehensibility of the instructions and items in the questionnaire. The pilot study was also used to check the logistics of administering the questionnaire – amount of time needed, instructions for the proctor, etc. All students completed the questionnaire within 15 minutes, including logging on to the computers, accessing the website, and completing the questionnaire. The selection of 16 students by grade level and school science experience was designed to minimize differences in age and science experience.

After the pilot administration of the questionnaire, students were interviewed in groups of three or four to identify any problem areas. It was apparent that the students understood the wording of the questions and their intent. In addition, two typographical errors were found and corrected.

In preparing to administer the questionnaire for the main study, it was identified that access to computers for completion of the survey would be an issue. Therefore, the questionnaire was printed and administered as a paper-and-pencil/pen version. Students were allotted 30 minutes to complete the questionnaire. Once completed, the questionnaires were sorted by the class in which they were administered and coded for data entry.

3.6 Data Analyses

Quantitative data were entered using Microsoft Excel. Students' responses were coded using Strongly Agree=5, Agree=4, Uncertain=3, Strongly Disagree=2, and Disagree=1. In addition, the class in which the questionnaire was administered and the student's science teacher were coded and entered into the spreadsheets. The data were uploaded to SPSS statistical analysis software for analysis.

3.6.1 Research Question 1

In order to answer the first research question – concerning whether learning environment scales based on the WIHIC, attitudes scales based on the TOSRA, and nature of science scales based on the SAI-II and VOSE were valid when used with my sample of secondary students from a Midwestern and suburban secondary school with urban demographics – factor analysis was applied to the scales. In order to yield meaningful results, items must all be indicators of some common underlying construct (Gardner, 1995):

> Factor analysis provides the strongest line of evidence to support a claim that a scale is unidimensional [*sic*]. A finding that all the items have substantial loadings on a single factor can be used to justify adding the item scores together to generate a single scale score. (p. 283)

Factor analysis (J. O. Kim & Mueller, 1978) is a statistical technique used in data reduction to identify a small number of underlying variables, or factors, that explain most of the variance observed in a much larger number of manifest variables. Using a separate factor analysis for the WIHIC, TOSRA and SAI-II/VOSE, I identified faulty items that could be removed to improve the factor structure and internal consistency reliability.

To examine the factor structure, and answer the first research question, the data were subjected to principal axis factor analysis with varimax rotation and Kaiser normalization separately for the learning environment items, the attitude items, and the nature of science items. In Chapter 4, it is reported that the analysis identified the Empirical Basis of Science scale as not meeting the two criteria for retention of any item – a factor loading of at least 0.4 with its own scale and less than 0.4 with all other scales – and it was removed.

In addition, the individual items should have a common underlying construct and therefore have internal consistency. A common measure of internal consistency is

Cronbach's alpha coefficient (Cronbach, 1951), which is high when every item in a scale shares a common variance with at least some other items in the scale and avoids clusters within a scale (Cronbach, 1951; Gardner, 1995).

A higher alpha value (i.e., closer to 1) indicates a more reliable scale, with a value of 0.7 being considered acceptable (Nunnally, 1978). Nunnally acknowledges that the level of reliability is situation dependent and that "in many applied settings a reliability of 0.80 is not nearly high enough. In basic research, the concern is with the size of correlations and with the differences in means for different experimental treatments, for which purposes a reliability of 0.80 for the different measures is adequate" (Nunnally, 1978, p. 245). However, he notes that "one saves time and energy by working with instruments that have only modest reliability, for which purpose reliabilities of 0.70 or higher will suffice" (Nunnally, 1978, p. 245).

Cronbach's alpha coefficient was used to provide a measure of the internal reliability of each WIHIC, TOSRA, and SAI-II/VOSE scale used in my study.

3.6.2 Research Question 2

In order to answer the second research question – concerning the characteristics of the science classroom environment that enhance students' attitudes to science and understanding of nature of science – simple correlation and multiple regression analyses were performed with the individual as the unit of analysis.

Simple correlation analysis (*r*) was used to identify the bivariate relationship between two specific variables (a learning environment scale and either an attitude scale or an understanding nature of science scale). The multiple correlation from multiple regression analysis provided information about the multivariate association between an attitude or understanding scale and the whole set of four environment scales. Standardized regression coefficients (β) were used to identify which environment scales contributed uniquely and significantly to the explanation of the variance in an attitude or an understanding scale when all the other WIHIC scales were mutually controlled.

3.7 Chapter Summary

This chapter discussed the methods used in my study for validating a questionnaire based on the WIHIC, TOSRA, SAI-II/VOSE scales and for investigating associations between the classroom learning environment and students' attitudes towards science and understanding of nature of science.

Section 3.3 described the development of the instrument based on the modification of four existing instruments – the WIHIC, TOSRA, SAI-II, and VOSE. The selection of the four scales of the WIHIC – Involvement, Investigation, Cooperation, and Task Orientation – was based on their relevance to the study. In the context of the study, Involvement measured the extent to which students perceived that they shared and communicated ideas; Investigation measured the extent to which students perceived that they engaged in problem solving; Cooperation measured the extent to which students perceived that they worked with others; and Task Orientation measured the extent to which students perceived that they knew the goals of the class and focused on them. The selection of the two scales of the TOSRA – Social Implications of

Science and Normality of Scientists – also was based on their relevance to the study. In the context of the study, Social Implications of Science measured the extent to which students appreciated the value of science and Normality of Scientists measured the extent to which students perceived that scientists look and act like people they know. The selection of the three NOS scales based on the SAI-II and VOSE – Tentative Nature of Science, Empirical Basis of Science, and Scientific Method – similarly was based on their relevance to the study. In the context of the study, Tentative Nature of Science measured the extent to which students understood that scientific knowledge changes, but not easily; Scientific Method measured the extent to which students understood that scientific methods depend on careful observations; Empirical Basis of Science measured the understanding that observation of natural phenomena and experimentation is the basis of scientific explanation and that science is limited in that it can only answer questions about natural phenomena and sometimes it is not able to do that. (However, the Empirical Basis of Science scale did not meet statistical criteria for retention as reported later in Chapter 4.)

Section 3.4 identified the 246 participants in the study as students in a Midwest USA suburban high school with urban demographics. No student completed the questionnaire in their science class.

Section 3.5 described how data were collected during a pilot study (whose aim was to check the readability and logistics of administration of the questionnaire) and in the main study. Because access to computers became an issue for the main study, students completed the questionnaire using paper-and-pencil/pen version.

Section 3.6 described the methods of statistical analysis for validating the questionnaire in order to answer the first research question concerning whether learning environment scales based on the WIHIC, attitudes scales based on the TOSRA, and nature of science scales based on the SAI-II and VOSE were valid when used with my sample. Factor analysis was used to check the structure of scales, whereas the alpha coefficient was used as an index of the internal reliability of each scale. This section also discussed the use of simple correlation and multiple regression analyses to answer the second research question concerning the characteristics of the science classroom environment that enhance students' attitudes to science and understanding of nature of science.

Whereas the present chapter (Chapter 3) was devoted to the research methods used in my study, the next chapter (Chapter 4) reports the analyses and results associated with my research questions.

Chapter 4

DATA ANALYSIS AND RESULTS

4.1 Introduction

The purposes of this research were two-fold: to validate modified versions of the WIHIC (What Is Happening In this Class?), TOSRA (Test of Science Related Attitudes), and SAI-II/VOSE (Scientific Attitudes Inventory/Views on Science and Education) in a medium, Midwestern, suburban secondary school with urban demographics; and to identify characteristics of the science classroom environment that enhance students' attitudes to science and understanding of nature of science.

Data were collected from a sample of 246 secondary school students as described in Section 3.4. These data were analyzed separately for the 32 WIHIC learning environment items, the 12 TOSRA attitude items, and the 18 SAI-II/VOSE nature of science items to check the validity. Once validated, the questionnaires were used to investigate associations between the constructs. The results are reported in the following sections:

- Details of the Questionnaire (4.2)
- Validity of WIHIC, TOSRA, SAI-II/VOSE (4.3)
- Relationships between Learning Environment and Student Outcomes of Attitudes and Understanding of Nature of Science (4.4)
- Chapter Summary (4.5).

4.2 Details of the Questionnaire

Modified versions of existing instruments were used in my study: the WIHIC was used to assess the learning environment; the TOSRA was used to assess student attitudes; and the SAI-II/VOSE was used to assess understanding of nature of science. These questionnaires were discussed in detail in Chapter 3 and are considered again briefly below in Sections 4.2.1 to 4.2.3.

The WIHIC, TOSRA, SAI-II,/VOSE all use a five-point response scale, with the original WIHIC using a frequency scale (Almost Always, Often, Sometimes, Seldom, and Almost Never) and the original TOSRA and SAI-II/VOSE using a Likert scale (Strongly Agree, Agree, Not sure, Disagree, and Strongly Disagree). The response scale for the WIHIC was modified to match the same Likert response scale as the TOSRA and SAI-II/VOSE (Strongly Agree, Agree, Not sure, Disagree, and Strongly Disagree) in order to avoid confusing students by having two different response scales and to maintain consistency throughout the questionnaire (see Section 3.3).

A small sample of students in their third or fourth years of secondary science (Grades 11 and 12) were involved in a pilot study to check the readability and comprehensibility of the instructions and items in the questionnaire. The pilot study was also used to check the logistics of administering the questionnaire – time, instructions for proctor, etc. The selection of 16 students minimized differences in grade levels and school science experience (see Section 3.5).

4.2.1 What Is Happening In this Class? (WIHIC)

The original What Is Happening In this Class? (WIHIC) consists of 56 items in seven scales: Student Cohesiveness, Teacher Support, Involvement, Investigation, Cooperation, Task Orientation, and Equity. The WIHIC has been used in numerous studies (Aldridge & Fraser, 2000) which showed it to be valid and reliable in describing the nature of classroom learning environments. A significant feature of the WIHIC is that it combines scales from previous instruments and includes contemporary dimensions (P. C. Taylor et al., 1997). My research used the Involvement, Investigation, Cooperation, and Task Orientation scales. Section 3.3.1 and Table 3.2 justify the selection of these four scales for my study.

4.2.2 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. The original version of the TOSRA consists of 70 items in seven scales: Social Implications for 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, 1981). It was developed to be used with secondary school science students (Dalgety et al., 2003). The TOSRA has been field tested and validated in Australia (Fraser, 1981), the United States (Khalili, 1987; Welch, 2010), Korea (Fraser & Lee, 2009; H. B. Kim et al., 2000), Singapore (Wong & Fraser, 1996) and Indonesia (Fraser, Aldridge, & Adolphe, 2010; Schibeci & Fraser, 1987). My research used the Social Implications for Science and Normality of Scientists scales. Table 3.2 and Section 3.3.2 justify how these two scales were chosen for my study because of their consistency with the national science education standards adopted in Illinois.

4.2.3 Scientific Attitudes Inventory: Revision (SAI-II) and Views on Science and Education (VOSE)

The Scientific Attitudes Inventory: Revision SAI-II is a revision of the original SAI that was altered in response to criticism about "…vocabulary, item difficulty, and format…" (Moore & Foy, 1997, p. 329). There are 36 items in the six position statements of the SAI-II: Tentative Nature of Science, Empirical Basis of Science, Scientific Method, Science as an Idea-Generating Activity, Necessity for Public Support of Science, and Personal Attributes Necessary for a Career in Science. Although the SAI-II uses the term 'attitude', it addresses understanding of nature of science topics such as the Tentative Nature of Science, Empirical Basis of Science, and Scientific Method (Lederman, 1992).

The original SAI contained 12 position statements (six positive and six negative). The statements are also categorized as intellectual or emotional attitudes, again with six statements for each attitude (Moore & Sutman, 1970). My research used the Tentative Nature of Science, Empirical Basis of Science, and Scientific Method scales. As discussed in Section 3.3.2, these scales were chosen because they were considered salient for my study.

The Views on Science and Education Questionnaire (VOSE) is based on the Views on Science-Technology-Society (VOSTS) questionnaire. As discussed in Section 2.7.1, the VOSTS was developed to avoid the assumption that the researcher and student would interpret an item in the same way (Aikenhead, 1988). The VOSE was designed to measure students' concepts of nature of science (NOS) and relevant teaching attitudes. The VOSE contains 15 questions followed by several items representing various philosophical positions to which students respond using a Likert scale (S. Chen, 2006a, 2006b). There are 10 questions addressing seven aspects of NOS and five questions covering the teaching attitudes corresponding to five of the NOS aspects. The seven NOS aspects are Tentativeness of Scientific Knowledge, Nature of Observation, Scientific Methods, Hypotheses, Laws, and Theories, Imagination, Validation of Scientific Knowledge, and Objectivity and Subjectivity in Science. The five teaching attitudes correspond to the five nature of science topics of Tentativeness of Scientific Knowledge, Nature of Observation, Scientific Methods, Hypotheses, Laws, and Theories, and Objectivity and Subjectivity in Science.

My research used the Tentativeness of Scientific Knowledge, Objectivity and Subjectivity in Science, and Scientific Methods scales. These scales were chosen because they were considered salient for my study and because of their consistency with national science education standards (see Table 3.2).

4.2.4 Validity of WIHIC, TOSRA and SAI-II/VOSE

The first purpose of this study was to validate my modified versions of the WIHIC, TOSRA, and SAI-II/VOSE with students from a medium, Midwestern secondary school in the USA with urban demographics. In order for a scale to yield meaningful results, the items must all be indicators of some common underlying construct (Gardner, 1995).

Factor analysis (J. O. Kim & Mueller, 1978) is used in data reduction to identify a small number of underlying variables, or factors, that explain most of the variance observed in a much larger number of manifest variables. Using separate data analysis for the WIHIC, TOSRA and SAI-II/VOSE, factor analysis was conducted in order to identify faulty items whose removal would improve the factor structure and internal consistency reliability. If the factor analysis results for an instrument with one sample are consistent with results from previous analyses with other samples, then that gives greater credibility to that instrument (Pallant, 2001).

In addition, the individual items should have a common underlying construct and therefore have internal consistency. Internal consistency is commonly used to provide a measure of scale reliability and provide information about the relationship among different items in the same scale. A common measure of internal consistency is Cronbach's alpha coefficient (Cronbach, 1951), which is maximized when every item in a scale shares a common variance with at least some other items in the scale and avoids clusters within a scale (Cronbach, 1951; Gardner, 1995). The higher the alpha value (i.e., closer to 1), the more reliable the scale is; a value of 0.7 is considered acceptable (Nunnally, 1978) (see discussion in Section 3.6).

Data collected from administering the questionnaires to my sample of 246 students were analyzed by performing principal axis factor analysis with varimax rotation and Kaiser normalization separately for: the 32 WIHIC learning environment items in four scales (namely, Involvement, Investigation, Cooperation and Task Orientation); the 12 TOSRA attitude items in two scales (Social Implications of Science and Normality of Scientists); and the 18 SAI-II/VOSE Nature of Science items in three scales (Tentative Nature of Science, Empirical Basis of Science, and Scientific Method). The two criteria for the retention of any item were that it must have a factor loading of at least 0.40 with its own scale and less than 0.40 with all other scales.

The data from the WIHIC, TOSRA, and SAI-II/VOSE were subjected to scale internal consistency analysis to investigate the extent to which items in the same scale measure a common construct. The internal consistency reliability, using Cronbach's alpha coefficient, was calculated for each of the eight refined WIHIC, TOSRA, and SAI-II/VOSE scales.

4.2.5 Factor Structure and Internal Consistency Reliability of WIHIC

With the goal of reducing the number of factors while maintaining important data, it was considered useful to refine the existing instruments slightly. Application of my two criteria for item retention (i.e. an item must have a factor loading of at least 0.4 with its own scale and less than 0.4 with all other scales) revealed that, with the exception of Item 4 from the Task Orientation scale, all items satisfied the criteria. A slightly-modified 31-item version of the WIHIC with the original four scales (Involvement, Investigation, Cooperation and Task Orientation), but with Item 4 omitted from the Task Orientation scale, was found to provide an optimal factor structure as shown by the factor loadings in Table 4.1.

The bottom of Table 4.1 shows the percentage of variance accounted for and the eigenvalue for each scale in the refined version of the WIHIC. Different WIHIC scales accounted for between 6.08% and 29.41% of the variance (total of 52.12%) and had eigenvalues ranging from 1.95 to 9.41 (Table 4.1).

Table 4.1 Factor Analysis Results for WIHIC Scales

Item No	Factor Loadings			
	Involvement	Investigation	Cooperation	Task Orientation
Invol 1	0.69			
Invol 2	0.70			
Invol 3	0.55			
Invol 4	0.66			
Invol 5	0.48			
Invol 6	0.49			
Invol 7	0.44			
Invol 8	0.59			
Invest1		0.67		
Invest 2		0.42		
Invest 3		0.59		
Invest 4		0.41		
Invest 5		0.69		
Invest 6		0.71		
Invest 7		0.67		
Invest 8		0.62		
Coop1			0.69	
Coop 2			0.54	
Coop 3			0.65	
Coop 4			0.62	
Coop 5			0.57	
Coop 6			0.77	
Coop 7			0.79	
Coop 8			0.62	
Task Orien 1				0.62
Task Orien 2				0.66
Task Orien 3				0.57
Task Orien 5				0.64
Task Orien 6				0.66
Task Orien 7				0.57
Task Orien 8				0.66
% Variance	9.91	6.72	29.41	6.08
Eigenvalue	3.17	2.15	9.41	1.95

N=246
Factor loadings less than 0.40 have been omitted from the table.
Principal axis factoring with varimax rotation and Kaiser normalization.
Item 4 in the Task Orientation scale was omitted.

The internal consistency reliability of each WIHIC scale was calculated using Cronbach's alpha coefficient. Table 4.2 shows that, with the student as the unit of analysis, alpha coefficients for the four WIHIC scales ranged from 0.84 to 0.87. The data in Table 4.1 and Table 4.2 support the conclusion that the four scales of the WIHIC were valid and reliable when used with my sample of 246 Midwestern high school students in the USA.

Table 4.2 Mean, Standard Deviation, and Internal Consistency Reliability (Alpha Coefficient) for Learning Environment, Attitude, and Nature of Science Scales

Scale	No of Items	Mean	SD	Alpha Reliability
Learning Environment				
Involvement	8	3.57	0.77	0.84
Investigation	8	3.43	0.74	0.86
Cooperation	8	4.12	0.66	0.87
Task Orientation	7	4.12	0.65	0.85
Attitudes				
Social Implications of Science	6	3.52	0.66	0.79
Normality of Scientists	6	3.52	0.66	0.82
Nature of Science				
Tentative Nature of Science	6	3.78	0.58	0.75
Scientific Method	5	3.87	0.57	0.70

N= 246
Factor loadings less than 0.40 have been omitted from the table.
Principal axis factoring with varimax rotation and Kaiser normalization.
Item 4 in the Task Orientation scale was omitted.

It is worth comparing how the factor structure and reliability for my research compare with previous studies involving the WIHIC. This study is consistent with a cross-national study in Australia, the UK, and Canada (Dorman, 2003) with 3980 students in Grades 8, 10, and 12. Dorman's data also supported the factorial invariance of the scales in that they functioned similarly across different populations. Dorman (2008) also reported a validation of the WIHIC using a multitrait–multimethod approach. Using a sample of 978 secondary school students in Australia, this study revealed the instrument was a valid measure of classroom environment.

Another cross-national study with 2960 junior high school students in Australia and Taiwan supported the factorial validity and reliability of the WIHIC to (Aldridge & Fraser, 2000). Fraser, Aldridge, and Adolphe (2010) also reported the factorial validity and reliability of the WIHIC with 1161 Australian and Indonesian secondary students. Another Indonesian version of the instrument (Wahyudi & Treagust, 2004) was found to be factorially valid and reliable for measuring the classroom learning environment in lower-secondary classroom with 1188 students.

Allen and Fraser (2007) found that the student and a parent versions of the WIHIC were factorially valid and reliable for a sample of 520 Grade 4 and 5 students and 120 of their parents in South Florida.

Den Brok, Fisher, Rickards and Bull (2006) found the WIHIC valid and reliable with 665 middle-school science students in California. Ogbuehi and Fraser (2007) also reported that the instrument was valid and reliable when used with 661 middle-school mathematics students in California. Wolf and Fraser (2008) reported that the WIHIC was factorially valid and reliable with a sample of 1434 middle-school physical science students in New York.

For a sample of 1404 students in Australia and Canada, Zandvleit and Fraser (2005) found the WIHIC exhibited sound factorial validity and reliability with students who were using computers. In Ontario, Canada, Fraser and Raaflaub (2013) found a modified WIHIC to be valid and reliable with a sample of 1172 secondary students using notebook computers.

The results of my study are similar to the studies discussed above in terms of validity and reliability. The WIHIC demonstrated a satisfactory factor structure and sound internal consistency reliability for my sample.

4.2.6 Factor Structure and Internal Consistency Reliability of TOSRA

When principal axis factoring with varimax rotation and Kaiser normalization was used with TOSRA data for my sample of 246 students, application of my two criteria for item retention (i.e. an item must have a factor loading of at least 0.4 with its own scale and less than 0.4 with all other scales) revealed that all items satisfied the criteria. The original 12-item version of the TOSRA with two scales (Social Implications of Science and Normality of Scientists), described in Table 4.3, was found to provide an optimal factor structure.

The bottom of Table 4.3 shows the percentage of variance and the eigenvalue for each scale in the refined version of the TOSRA. The two scales of the TOSRA accounted for 13.29% and 38.04% of the variance (total of 51.33%) for the TOSRA and had eigenvalues of 1.59 and 4.56 (Table 4.3).

Table 4.3 Factor Analysis Results for TOSRA Scales

Item No	Factor Loadings	
	Social Implications of Science	Normality of Scientists
Social Implications 1	0.55	
Social Implications 2	0.49	
Social Implications 3	0.63	
Social Implications 4	0.68	
Social Implications 5	0.74	
Social Implications 6	0.49	
Normality 1		0.51
Normality 2		0.75
Normality 3		0.68
Normality 4		0.66
Normality 5		0.51
Normality 6		0.59
% Variance	13.29	38.04
Eigenvalue	1.59	4.56

N=246

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

Principal axis factoring with varimax rotation and Kaiser normalization.

As Table 4.2 shows, with the student as the unit of analysis, alpha coefficients for the two scales of the TOSRA were 0.79 and 0.82. The data in Table 4.2 and Table 4.3 support the conclusion that the two scales of the TOSRA were valid and reliable for my sample.

Because my study incorporated two scales from the TOSRA, it is also worth noting how the factor structure and reliability compare with previous studies involving the TOSRA. Using an Australian sample of 1337 students in grades 7 through 10, the scales of the TOSRA were found to have appropriate validity and internal consistency reliability (Fraser, 1978).

In Florida, selected scales from the TOSRA exhibited sound factorial validity and reliability with 172 kindergarteners and 78 of their parents (Robinson & Fraser, 2013), in Spanish with 223 elementary students (Adamski et al., 2013), and in English and Spanish with 1105 Grade 2 to Grade 5 students (Soto-Rodriguez, 2005). For a sample of 25 chemistry teachers and 224 high-school students in Alabama, the TOSRA was found to be reliable when it was used as part of an evaluation of a state-wide in-service and outreach program (Lott, 2002). As part of the evaluation of the Alliance+ program involving seven teachers and 759 middle-school students in Florida, the TOSRA was found to be valid and reliable (Biggs, 2008). In the evaluation of a program at Challenger Learning Centers with 311 students and seven teachers using live simulations to study Earth Science, Chen and Howard (2010) found that the TOSRA had satisfactory reliability and an appropriate factor structure.

The TOSRA has also been found valid and reliable in Brunei Darussalam by den Brok, Fisher, and Scott (2005) who reported that it exhibited satisfactory reliability and an appropriate factor structure with a 1305 students aged nine to 14 years. Similarly, Anwer, Iqbal, and Harrison (2012) found support for the TOSRA's validity with a sample of 3526 Grade 10 students in Pakistan.

In Australia, Fisher and Waldrip (1999) reported that the TOSRA was valid and reliable with a sample of 3785 secondary science students. Fraser, Aldridge, and Adolphe (2010), in a cross-national study in Australia and Indonesia, found the TOSRA to be reliable and have a strong factor structure with a sample 1161 secondary science students.

The results of my study are similar to those reported in the studies reviewed above in terms of validity and reliability. The TOSRA demonstrated both a sound factor structure and satisfactory internal consistency reliability with my sample.

4.2.7 Factor Structure and Internal Consistency Reliability of SAI-II/VOSE

When factor analysis was conducted for my three-scale version of the SAI-II/VOSE with my sample of 246 students, application of my two criteria for item retention (i.e. an item must have a factor loading of at least 0.4 with its own scale and less than 0.4 with all other scales) revealed that the entire Empirical Basis of Science scale (SAI-II Empirical Basis of Science and VOSE Objectivity and Subjectivity in Science scales) and Item 6 from the Scientific Method scale (VOSE Scientific Methods scale) did not satisfy the criteria. A modified 11-item version of the SAI-II/VOSE with the original Empirical Basis of Science scale removed entirely and with Item 6 removed from the Scientific Method scale (see Table 4.4) was found to be to provide an optimal factor structure.

The bottom of Table 4.4 shows the percentage of variance and the eigenvalue for each scale in the refined version of the SAI-II/VOSE. The two scales of the SAI-II/VOSE accounted for 13.00% and 32.78% of the variance (total of 45.78%) and had eigenvalues of 1.43 and 3.61 (see Table 4.4).

Table 4.4 Factor Analysis Results for SAI-II/VOSE Scales

Item No	Factor Loadings	
	Tentative Nature Of Science	Scientific Methods
Tentative Nature 1	0.64	
Tentative Nature 2	0.66	
Tentative Nature 3	0.43	
Tentative Nature 4	0.62	
Tentative Nature 5	0.40	
Tentative Nature 6	0.56	
Scientific Method 1		0.52
Scientific Method 2		0.48
Scientific Method 3		0.40
Scientific Method 4		0.57
Scientific Method 5		0.65
% Variance	32.78	13.00
Eigenvalue	3.61	1.43

N=246
Factor loadings less than 0.40 have been omitted from the table.
Principal axis factoring with varimax rotation and Kaiser normalization.
Item 6 in the Scientific Method scale and the entire Empirical Basis of Science scale were omitted.

Because my study used scales from the SAI-II and VOSE, it is worth noting how the validity and reliability with my sample compare with previous studies involving the SAI-II and VOSE. Using a sample of 557 Grade 6, 9, and 12 rural/suburban students, Moore and Foy (1997) reported that the total SAI-II had a Cronbach alpha coefficient of 0.781, but they provided no evidence to support from factor analysis. Content validity of the SAI-II was claimed on the basis of data obtained from a panel of judges and high-school students. Items selected received the greatest support from the judges *and* were neither unanimously endorsed nor rejected by the students

(Moore & Sutman, 1970). Similarly, construct validity of the SAI-II was claimed based on the demonstrated validity of the SAI in the original field test. However, the SAI-II was able to distinguish between the responses of the upper and lower 27% of respondents for the total instrument when compared with their scores on the various subscales.

A Turkish translation of the SAI-II was used with a sample of 300 middle-school students (Demirbaş & Yağbasan, 2006) and found to have a Cronbach alpha coefficient of 0.76 for the entire instrument. Also an alpha coefficient of 0.72 was found when piloted with a sample of 100 Turkish science teachers (Demirbaş, 2009). In another Turkish study with preservice elementary teachers (Cavas et al., 2013), SAI-II had an alpha reliability coefficient of 0.72.

The SAI-II has also been translated into Thai. When used in a study with a sample of 94 Grade 7 students, the Thai version's total score was found to have an alpha coefficient of 0.81 (Cojorn et al., 2013). A version of the SAI-II modified for the Indian context was used in a study of 300 preservice teachers from four teacher training colleges and found to have an alpha reliability of 0.927 (Lahiri, 2011).

In the USA, the SAI-II was found to have an alpha coefficient of 0.78 when used in a study with a sample of 117 Grade 11 students (Liang, 2002). In the Boston Public Schools, a modified version of the SAI-II was used over a two-year period with secondary science students (Barnett et al., 2006) and found to have reliabilities ranging from 0.67 to 0.85. In New Mexico, a modified SAI-II was used with a sample of 95 middle-school students, 88% of whom self-identified as Hispanic (Sorge et al., 2000), and was found to an alpha coefficient of 0.734.

At the post-secondary level in the USA, when Nadelson and Viskupic (2010) used the SAI-II with a sample of 61 lower- and upper-division geoscience students, they reported a Cronbach alpha coefficient of 0.83. In another study with 89 preservice teachers from two universities (Nadelson & Sinatra, 2010), an alpha coefficient of 0.79 was reported.

The studies reviewed above either neglected to address validity or they followed Moore and Foy (1997) and claimed only content and construct validity for the original SAI. This could be explained by researchers viewing items to be only open to one interpretation and therefore not requiring validation (Tytler & Osborne, 2012).

The results of my study for the SAI-II/VOSE are similar to those of studies discussed above in terms of alpha reliability (but past studies did not report factor structure). The SAI-II/VOSE has demonstrated satisfactory internal consistency reliability and factorial validity with my sample.

4.2.8 Relationships between Learning Environment and Student Outcomes of Attitudes and Understanding of Nature of Science

The second purpose of this study was to identify characteristics of the science classroom environment that enhance students' attitudes to science and understanding of nature of science. Simple correlation analysis (r) was used for examining the bivariate relationship between one environment scale and one outcome scale.

Multiple regression analysis provided information about the multivariate association between an attitude or understanding scale and the set of four environment scales. Standardized regression coefficients (β) were used to identify which environment scales contributed uniquely and significantly to the explanation of the variance in an attitude or an understanding scale when all the other WIHIC scales were mutually controlled.

Associations between students' perceptions of the classroom environment (as assessed by four WIHIC's scales), their attitudes towards science (as assessed by two TOSRA scales) and their understanding of nature of science (as assessed by two SAI-II/VOSE scales) are reported in Table 4.5. These associations were investigated using the sample of 246 students in a medium Midwestern secondary school with urban demographics. The statistics reported in Table 4.5 are the simple correlations, standardized regression coefficients and multiple correlations between each TOSRA or SAI-II/VOSE scale and the four learning environment scales of the WIHIC.

Table 4.5 Simple Correlations and Multiple Regression Analyses for Associations Between Learning Environment Scales and Student Outcomes of Attitudes to Science and Nature of Science

Scale	Social Implications of Science		Normality of Scientists		Tentative Nature of Science		Scientific Method	
	r	β	*r*	β	*r*	β	*r*	β
Involvement	0.35**	0.00	0.30**	0.11	0.21**	0.12	0.23**	0.05
Investigation	0.49**	0.36**	0.27**	0.07	0.32**	0.21**	0.33**	0.24**
Cooperation	0.33**	0.06	0.29**	0.08	0.34**	0.16*	0.30**	0.12
Task Orientation	0.44**	0.28**	0.37**	0.28**	0.42**	0.32**	0.35**	0.24**
Multiple Correlation *R*	0.57**		0.43**		0.48**		0.43**	

$*p<0.05$, $**p<0.01$
N=246

Table 4.5 shows that, with the individual student as the unit of analysis, each of the four environment scales was statistically significantly correlated ($p<0.01$) with each attitude scale (Social Implications and Normality of Scientists) and to each nature of science scale (Tentative Nature of Science and Scientific Method).

The multiple correlations (R) reported at the bottom of Table 4.5 for the set of four WIHIC scales was statistically significant ($p<0.05$) for each of the two attitude and two understanding scales.

To identify which classroom environment scales contributed most to the variance in a specific attitude or understanding scale, the standardized regression weights (β) were examined and yielded the following results:

- Investigation and Task Orientation were positively, significantly, and independently related to Social Implications of Science.
- Task Orientation was positively, significantly, and independently related to Normality of Scientists.
- Investigation, Cooperation, and Task Orientation were positively, significantly, and independently related to Tentative Nature of Science.
- Investigation and Task Orientation were positively, significantly, and independently related to Scientific Method.

It is noteworthy that every statistically significant simple correlation and regression coefficient in Table 4.5 was positive, suggesting that a positive relationship existed between a more favorable classroom learning environment and students' attitudes and understanding of the nature of science. This replicates considerable prior research with the WIHIC (Chionh & Fraser, 2009; Fraser, Giddings, & McRobbie, 1995; Martin-Dunlop & Fraser, 2008; McRobbie & Fraser, 1993) reviewed in Section 2.5.1 and Table 2.3.

Some particular associations in Table 4.5 between students' perceptions of their learning environments and their attitudes towards or understanding of science are noteworthy. Investigation and Task Orientation had stronger multivariate associations with attitudes/understanding than did the other two WIHIC scales of Involvement and Cooperation. In fact, Involvement had a significant independent association with none of the four attitude or understanding scales.

4.3 Chapter Summary

This chapter reported analyses and results for the two research questions in this study – to validate the WIHIC, TOSRA, and SAI-II/VOSE in a medium, Midwestern United States, suburban secondary school with urban demographics; and to identify characteristics of the science classroom environment that enhance students' attitudes to science and understanding of nature of science.

The What Is Happening In this Class? (WIHIC) was modified to provide four scales: Involvement, Investigation, Cooperation, and Task Orientation. Similarly, two scales from the Test Of Science Related Attitudes (TOSRA) were modified and used: Social Implications of Science and Normality of Scientists. As well, two scales from the Scientific Attitudes Inventory Revised (SAI-II) and the Views On Science and Education (VOSE) were modified and used: Tentative Nature of Science and Scientific Method. Data from 246 secondary school students in the Midwest were statistically analyzed to answer these questions. The SAI-II/VOSE Empirical Basis of Science/Objectivity and Subjectivity in Science scale was omitted following factor analysis.

As described in Chapter 3, modified versions of the WIHIC, TOSRA, SAI-II/ VOSE were assembled into a single instrument for ease of administration. The validity and the reliability of each component of the instrument were checked for factor structure and internal consistency reliability. To examine the factor structure, and answer the first research question, data were subjected to principal axis factor analysis with varimax rotation and Kaiser normalization separately for the 32 WIHIC learning environment items in four scales, the 12 TOSRA attitude items in two scales, and the 18 SAI-II/VOSE nature of science items in three scales.

The two 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 each of the other scales. Application of these criteria led to eight items being removed (Item 4 from the Task Orientation and Item 6 from Scientific Method scale, as well as the entire Empirical Basis of Science scale), reducing the original 62 items to 54.

The percentage of variance ranged between 6.08% and 29.41% for the four WIHIC scales, totaling 52.12%, and the eigenvalues ranged from 1.95 to 9.41 (see Table 4.1). The percentage of variance for the TOSRA for the two scales was 13.29% and

38.04%, totaling 51.33%, and the eigenvalues were 1.59 and 4.56 (see Table 4.3). The percentage of variance for the SAI-II/VOSE for the two scales was 13.00% and 32.78%, totaling of 45.78%, and the eigenvalues were 1.43 and 3.61 (see Table 4.4). The percentage of variance, the eigenvalues and the factor loadings support the factor structure of the modified scales of the WIHIC, TOSRA, and SAI-II/VOSE.

Internal consistency was used to provide a measure of scale reliability and provide information about the relationship among different items on the scale. A Cronbach alpha value of 0.7 generally is considered acceptable. When using the individual as the unit of analysis, alpha values for WIHIC scales ranged between 0.84 and 0.87, with the lowest alpha value being found for the Involvement scale and the highest for the Cooperation scale (see Table 4.2). Scale alpha values for the TOSRA were 0.79 and 0.82, with the lower alpha coefficient for the Social Implications of Science scale and the higher value for the Normality of Scientists scale (see Table 4.2). Scale alpha values for the SAI-II/VOSE were 0.70 and 0.75, with the lower value for the Scientific Method scale and the higher coefficient for the Tentative Nature of Science scale (see Table 4.2).

To answer my second research question, the data were analyzed to determine associations between students' perception of the classroom learning environment and their attitudes toward science and understanding of nature of science. Simple correlation analysis was used to examine the bivariate relationship between each of the classroom learning environment scales and each of the two attitude scales and two understanding on nature of science scales. Multiple regression analysis was used to investigate the multivariate association between a student outcome measure and the set of four learning environment scales. Standardized regression coefficients were used to identify which environment scales contributed uniquely and significantly to explaining the variance in an attitude or understanding scale when all of the other learning environment scales were mutually controlled.

The results of the simple correlation analysis indicate that all four of the learning environment scales were statistically significantly associated with both attitude scales (Social Implications for Science and Normality of Scientists) and both understanding scales (Tentative Nature of Science, and Scientific Method). Correlations with learning environment scales ranged: between 0.33 and 0.49 for Social Implications for Science; between 0.27 and 0.37 for Normality of Scientists; between 0.21 and 0.42 for Tentative Nature of Science; and between 0.23 and 0.35 for Scientific Method (see Table 4.5). The results suggest that greater emphasis on the classroom learning environment dimensions investigated in my study – Involvement, Investigation, Cooperation, and Task Orientation – is linked with improved student attitudes toward science and understanding of nature of science.

The multiple correlation between the four learning environment scales and each of the two attitude and two understanding scales was statistically significant. The multiple correlation for the set of learning environment scales was 0.57 for Social Implications, 0.43 for Normality, 0.48 for Tentative Nature of Science, and 0.43 for Scientific Method. The result suggests the classroom learning environment was related to student attitudes to science and understanding of nature of science.

Using the standardized regression weights, Investigation and Task Orientation were statistically significant independent predictors of Social Implications of Science and Scientific Method. Task Orientation was a statistically significant independent predictor of student attitudes to the Normality of Scientists. Investigation, Cooperation, and Task Orientation were statistically significant independent predictors of student understanding of the Tentative Nature of Science.

It is worth noting that Investigation and Task Orientation had stronger multivariate associations with attitudes and understanding than did Involvement and Cooperation. Overall, my results suggest the existence of statistically significant associations between students' learning environment and their attitude to science and understanding of nature of science, which replicates past research (Burton, 2013; M. C. Lai, 2012; Liang, 2002; P. R. Smith, 2013), including studies reviewed in Section 2.5.1.

Chapter 5

DISCUSSION AND CONCLUSION

5.1 Introduction

My study was conducted at a medium, suburban secondary school with urban demographics in Midwestern USA. Data collected from 246 secondary-school students were analyzed separately for my modified versions of a learning environment instrument (WIHIC), attitude instrument (TOSRA), and nature of science instrument (SAI-II/VOSE). In addition, I investigated associations between the learning environment and student attitudes toward science and understanding of nature of science. The chapter includes the following sections:

- Summary of Chapters 1–3 (5.2)
- Summary of Research Findings (5.3)
- Significance and Implications (5.4)
- Limitations (5.5)
- Suggestions for Future Research (5.6)
- Chapter Conclusion (5.7).

5.2 Summary of Chapters 1–3

Chapter 1 briefly provided background and contextual information in order to set the scene for my study. My two research questions were delineated and selected literature was reviewed for each of the three constructs in my study: learning environment, attitudes to science, and understanding of the nature of science (NOS). As well as identifying the significance of my research, Chapter 1 also provided an overview of the other chapters in this thesis.

Chapter 2 was devoted to reviewing literature pertinent to my study. The topic most comprehensively covered was the field of learning environments, including its historical background, a range of questionnaires for assessing students' perceptions of their classroom environment, especially the instrument (What Is Happening In this Class?, WIHIC) employed in my research, and types of past learning environment research. A section was devoted to the assessment of attitudes to science, including the Test of Science Related Attitudes (TOSRA) that was modified for use in my research. Finally, the literature review focused on understanding the nature of science (NOS) and encompassed questionnaires from which scales were drawn for my study – the Scientific Attitude Inventory Revision (SAI-II) and Views on Science and Education (VOSE).

Chapter 3 was devoted to research methods, beginning with a description of my study's learning environment scales (from the What Is Happening In this Class?, WIHIC), attitude to science scales (from the Test of Science Related Attitudes, TOSRA) and understanding of NOS scales (SAI-II/VOSE). My questionnaire consisted of

- 32 learning environment items based on the WIHIC for assessing Involvement, Investigation, Cooperation, and Task Orientation
- 12 attitude items based on the TOSRA for assessing Social Implications of Science and Normality of Scientists

- 18 NOS items based on SAI-II/VOSE for assessing Tentative Nature of Science, Empirical Basis of Science, and Scientific Method.

Data-collection methods with my sample of 246 secondary-school students were considered. Finally, it was identified that the main methods of data analysis would be factor analysis for questionnaire validation and multiple regression analysis for exploring the association of learning environment with students' attitudes and understanding of NOS.

5.3 Summary of Research Findings

The validity of the questionnaire was examined using a principal axis factor analysis with varimax rotation and Kaiser normalization separately for the learning environment items, the attitude items, and the nature of science items. The criteria for retention of any item were that it must have a factor loading of at least 0.4 with its own scale and less than 0.4 with all of the other scales.

For the WIHIC, application of my two criteria for item retention (i.e. a factor loading of at least 0.4 with its own scale and less than 0.4 with all other scales) revealed that, with the exception of Item 4 from the Task Orientation scale, all items satisfied the criteria. A slightly-modified 31-item version of the WIHIC with the original four scales (Involvement, Investigation, Cooperation, and Task Orientation), but with Item 4 omitted from the Task Orientation scale, was found to provide an optimal factor structure. The four scales of the WIHIC accounted for between 6.08% and

29.41% (total of 52.12%) of the variance and had eigenvalues ranging from 1.95 to 9.41.

When principal axis factoring with varimax rotation and Kaiser normalization was used with TOSRA data, application of my two criteria for item retention revealed that all items satisfied the criteria. The original 12-item version of the TOSRA with two scales (Social Implications of Science and Normality of Scientists) was found to provide an optimal factor structure. The two scales of the TOSRA accounted for 13.29% and 38.04% (total of 51.33%) of the variance and had eigenvalues of 1.59 and 4.56.

When factor analysis was conducted for my three-scale version of the SAI-II/VOSE, application of my two criteria for item retention revealed that the entire Empirical Basis of Science scale and Item 6 from the Scientific Method scale did not satisfy the criteria. A modified 11-item version of the SAI-II/VOSE with the original Empirical Basis of Science scale removed entirely and with Item 6 removed from the Scientific Method scale was found to be to provide an optimal factor structure. The two scales in the refined version of the SAI-II/VOSE accounted for 13.00% and 32.78% (total of 45.7%) of the variance and had eigenvalues of 1.43 and 3.61.

Not only was the factor structure of the modified scales of the WIHIC, TOSRA, and SAI-II/VOSE supported, but also Cronbach's alpha coefficient for different scales ranged from 0.70 to 0.87. Therefore data analyses support the conclusion that the modified scales from the WIHIC, TOSRA and SAI-II/VOSE were valid and reliable for my sample. This finding is especially pertinent for the SAI-II/VOSE scales because support for factorial validity had not been reported in the past research.

To answer my second research question, data were analyzed to determine associations between students' perception of the classroom learning environment and their attitudes toward science and understanding of nature of science. The results of simple correlation analysis indicated that all four learning environment scales were statistically significantly associated with both attitude scales (Social Implications for Science and Normality of Scientists) and both understanding scales (Tentative Nature of Science, and Scientific Method). The multiple correlation was statistically significant between the four learning environment scales and each of the two attitude and two understanding scales.

Using the standardized regression weights, Investigation and Task Orientation were statistically significant independent predictors of student attitudes to the Social Implications of Science and understanding of Scientific Method. Task Orientation was a statistically significant independent predictor of student attitudes to the Normality of Scientists. Investigation, Cooperation, and Task Orientation were statistically significant independent predictors of student understanding of the Tentative Nature of Science.

Overall, the results of my study suggest the existence of statistically significant associations between students' learning environment and their attitude to science and understanding of nature of science. These results suggest that greater emphasis on the classroom learning environment dimensions investigated in my study – Involvement, Investigation, Cooperation, and Task Orientation – is linked with improving student attitudes toward science and understanding of nature of science. In general, these findings replicate the results of many past studies of associations between classroom environment and student outcomes (Fraser, 2012, 2014).

5.4 Significance and Implications

My research is substantively significant in that it brought together in a single study the three separate fields of learning environment, attitudes to science, and understanding of the nature of science (NOS). Only a very small number of prior learning environment studies have explored the influence of the classroom environment on students' understanding of NOS.

A methodological contribution is that my research involved developing and validating with secondary-school students in Midwestern USA some widely-applicable and useful questionnaire scales for assessing classroom environment, attitude to science, and understanding of NOS. In particular, my research probably is the first study to provide evidence of the factorial validity of NOS scales based on the SAI-II and VOSE.

The practical implication of my study is that teachers are provided with research evidence about what emphases in the classroom environment are likely to improve their students' attitudes to science and understanding of NOS. In particular, positive student attitudes to science and better student understanding of NOS are likely to be promoted in classrooms with more investigation and task orientation.

5.5 Limitations

As with all educational research, my study had limitations. The first limitation was associated with my sample. Because my sample size was only 246 students, inevitably, the statistical power of data analyses would have been limited and, as well, it wasn't feasible to employ the class mean as the unit of statistical analysis. Because my sample was drawn from a single school, the generalizability of my results to other schools would be limited.

Although data analyses conducted with my data supported the validity and reliability of my modified measure of classroom environment (WIHIC), attitudes (TOSRA) and understanding of nature of science (SAI-II/VOSE), still it is possible that any modifications made could have led to some loss of validity. Clearly, further cross-validation in future studies would be desirable.

Tobin and Fraser (1998) have articulated the merits of combining quantitative and qualitative methods in learning environment research. Unfortunately, practical constraints associated with time limitations and coordination of schedules make the collection of extensive qualitative information (e.g. student interviews) impractical. Therefore, the lack of quality information to complement quantitative questionnaire data in my study was a limitation.

Although the types of data analysis used in my study were both sophisticated and useful, it is always possible to conduct alternative and even more-elaborate types of analysis. For example, whereas my analyses were limited to exploratory factor analysis (for scale validation) and multiple regression analyses (for outcome–environment associations), additional analyses that could be considered in future research include confirmatory factor analysis and multilevel analysis.

Having only two scales to measure each construct (learning environment, attitudes and NOS) is potentially a limitation. Possibly having more or different constructs might have led to some different patterns of findings.

5.6 Suggestions for Future Research

Given the promising findings from this study, it is recommended that it is replicated and expanded in future research by including other educationally-important constructs (e.g. student achievement) and reducing the above limitations associated with my research.

The limitations identified in the previous section lead to these suggestions for future research:

- Involve a more-representative and diverse sample to enhance the generalizability of findings
- Increase the sample size to improve the statistical power of data analyses
- Cross-validate questionnaires with different samples to increase confidence in their use
- Complement quantitative questionnaire data with qualitative information from interviews and classroom observations

- Undertake additional types of data analysis such as confirmatory factor analysis and multilevel analysis
- Add more scales to assess other aspects of the constructs included in my study (learning environment, attitudes and NOS).

5.7 Chapter Conclusion

This study of the learning environments of secondary-school science classrooms has illuminated what characteristics of the learning environment promote more positive attitudes to science and better understanding of the nature of science.

When teachers assess their students and classrooms, they typically consider only achievement and not the factors that might influence their students' successful outcomes (Fraser, 1989). Hopefully my study will encourage teachers to evaluate their classroom environments and their effect on student outcomes.

In an increasingly technological and scientific society, citizens must be scientifically literate. Considering that the learning environment does have an effect on student cognitive and affective outcomes, it is important to continue to study this relationship between the learning environment and outcomes.

REFERENCES

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

Afari, E., Aldridge, J. M., Fraser, B. J., & Khine, M. S. (2013). Students' perceptions of the learning environment and attitudes in game-based mathematics classrooms. *Learning Environments Research, 16*, 131-150. doi: 10.1007/s10984-012-9122-6

Aikenhead, G. S. (1988). An analysis of four ways of assessing student beliefs about STS topics. *Journal of Research in Science Teaching, 25*, 607-629.

Aikenhead, G. S., & Ryan, A. G. (1992). The development of a new instrument: "Views on science-technology-society" (VOSTS). *Science Education, 76*, 477-491.

Aikenhead, G. S., Ryan, A. G., & Fleming, R. W. (1989). *Views on science-technology-society* Saskatoon: University of Saskatchewan.

Aldridge, J. M., Dorman, J. P., & Fraser, B. J. (2004). Use of Multitrait-Multimethod Modelling to Validate Actual and Preferred Forms of the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI). *Australian Journal of Educational & Developmental Psychology, 4*, 110-125.

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

Aldridge, J. M., Fraser, B. J., Bell, L., & Dorman, J. P. (2012). Using a New Learning Environment Questionnaire for Reflection in Teacher Action

Research. *Journal of Science Teacher Education, 23*, 259-290. doi: 10.1007/s10972-012-9268-1

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

Aldridge, J. M., Fraser, B. J., & Laugksch, R. C. (2011). Relationships between the school-level and classroom-level environment in secondary schools in South Africa. *South African Journal of Education, 31*, 127-144.

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

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

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

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

Alters, B. J. (1997). Whose nature of science? *Journal of Research in Science Teaching, 34*, 39-55.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Anderson, G. J. (1973). *The assessment of learning environments: A Manual for the Learning Environment Inventory and the My Class Inventory*. Halifax, Nova Scotia, Canada: Atlantic Institute of Education.

Anderson, G. J., & Arsenault, N. (1998). *Fundamentals of educational research* (2nd ed.). New York: Falmer.

Anwer, M., Iqbal, H. M., & Harrison, C. (2012). Students' attitude towards science: A case of Pakistan. *Pakistan Journal of Social and Clinical Psychology, 9*, 3-9.

Bandura, A. (1978). The self system in reciprocal determinism. *American Psychologist, 33*, 344-358.

Barnett, M., Lord, C., Strauss, E., Rosca, C., Langford, H., Chavez, D., & Deni, L. (2006). Using the urban environment to engage youths in urban ecology field studies. *The Journal of Environmental Education, 37*, 3-11.

Belardo, C. (2001). *Inspiring future scientists: Developing a science enrichment program for teens* Retrieved from http://www.ansp.org/education/pdf/Inspiring_Future_Scientist.pdf

Bennett, J. (2001). The development and use of an instrument to assess students' attitude to the study of chemistry. *International Journal of Science Education, 23*, 833-845.

Biggs, E. M. (2008). *Evaluation of a professional development program on integrating technology into middle schools: Classroom environment and student attitudes.* Unpublished doctoral thesis, Curtin University of Technology, Science and Mathematics Education Centre, Perth.

Blalock, C. L., Lichtenstein, M. J., Owen, S., Pruski, L., Marshall, C., & Toepperwein, M. (2008). In pursuit of validity: A comprehensive review of science attitude instruments 1935–2005. *International Journal of Science Education, 30*, 961-977.

Brekelmans, M., Levy, J., & Rodriguez, R. (1993). A typology of teacher communication style. In T. Wubbels & J. Levy (Eds.), *Do you know what you look like?: Interpersonal relationships in education* (pp. 46-55). London: Falmer Press.

Brekelmans, M., Mainhard, T., den Brok, P., & Wubbels, T. (2011). Teacher control and affiliation: Do students and teachers agree? *Journal of Classroom Interaction, 46*, 17-26.

Bruce, B. C., Bruce, S. P., Conrad, R. L., & Huang, H. J. (1997). University science students as curriculum planners, teachers, and role models in elementary school classrooms. *Journal of Research in Science Teaching, 34*(1), 69-88.

Burden, R. L., & Fraser, B. J. (1993). Use of classroom environment assessments in school psychology: A British perspective. *Psychology in the Schools, 30*, 232-240.

Burton, E. P. (2013). Student work products as a teaching tool for nature of science pedagogical knowledge: A professional development project with in-service secondary science teachers. *Teaching and Teacher Education, 29*, 156-166.

Cavas, P. H., Ozdem, Y., Cavas, B., Cakiroglu, J., & Ertepinar, H. (2013). Turkish pre-service elementary science teachers' scientific literacy level and attitudes toward science. *Science Education International, 24*, 383-401.

Chen, C. H., & Howard, B. C. (2010). Effect of live simulation on middle school students' attitudes and learning toward science. *Educational Technology & Society, 13*, 133-139.

Chen, S. (2006a). Development of an instrument to assess views on nature of science and attitudes toward teaching science. *Science Education, 90*, 803-819.

Chen, S. (2006b). Views on Science and Education (VOSE) questionnaire. *Asia-Pacific Forum on Science Learning and Teaching, 7,* Article 11. http://www.ied.edu.hk/apfslt/download/v7_issue2_files/chensf.pdf

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

Cleminson, A. (1990). Establishing an epistemological base for science teaching in the light of contemporary notions of the nature of science and of how children learn science. *Journal of Research in Science Teaching, 27*, 429-445.

Cohn, S. T., & Fraser, B. J. (in press). Effectiveness of student response systems in terms of learning environment, attitudes and achievement. *Learning Environments Research*.

Cojorn, K., Koocharoenpisal, N., Haemaprasith, S., & Siripankaew, P. (2013). Effects of the Creative Problem Solving (CPS) learning model on matter and properties of matter for seventh grade students. *Journal of Education, 35*, 18-30.

Cooley, W. W., & Klopfer, L. E. (1963). The evaluation of specific educational innovations. *Journal of Research in Science Teaching, 1*, 73-80.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16*, 297-334.

Dalgety, J., Coll, R. K., & Jones, A. (2003). Development of chemistry attitudes and experiences questionnaire (CAEQ). *Journal of Research in Science Teaching, 40*, 649-668.

Demirbaş, M. (2009). The relationships between the scientist perception and scientific attitudes of science teacher candidates in Turkey: A case study. *Scientific Research and Essays, 4*, 565-576.

Demirbaş, M., & Yağbasan, R. (2006). Fen bilgisi öğretiminde bilimsel tutumların işlevsel önemi ve bilimsel tutum ölçeğinin Türkçeye uyarlanma çalışması [The functional importance of scientific attitudes in science teaching and adaptation of scientific attitude scale into Turkish]. *Uludağ üniversitesi eğitim fakültesi dergisi, 19*, 271-299.

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

den Brok, P., Fisher, D., & Scott, R. H. (2005). The importance of teacher interpersonal behaviour for student attitudes in Brunei primary science classes. *International Journal of Science Education, 27*, 765-779. doi: 10.1080/09500690500038488

Doran, R. L., Guerin, R. O., & Cavalieri, J. (1974). An analysis of several instruments measuring “nature of science” objectives. *Science Education, 58*, 321-329.

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

Dorman, J. P. (2008). Use of multitrait–multimethod modelling to validate actual and preferred forms of the What Is Happening In this Class?(WIHIC) questionnaire. *Learning Environments Research, 11*, 179-193.

Dorman, J. P., Aldridge, J. M., & Fraser, B. J. (2006). Using students' assessment of classroom environment to develop a typology of secondary school classrooms. *International Education Journal, 7*, 906-915.

Dorman, J. P., & Ferguson, J. M. (2004). Associations between students' perceptions of mathematics classroom environments and self-handicapping in Australian and Canadian high schools. *McGill Journal of Education, 39*(1), 69-86.

Eidietis, L., & Jewkes, A. M. (2011). Making curriculum decisions in K–8 science: The relationship between teacher dispositions and curriculum content. *Journal of Geoscience Education, 59*, 242-250.

Fennema, E., & Sherman, J. A. (1976). Fennema-Sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males. *Journal for Research in Mathematics Education, 7*, 324-326. doi: 10.2307/748467

Ferguson, P. D., & Fraser, B. J. (1998). Changes in learning environment during the transition from primary to secondary school. *Learning Environments Research, 1*, 369-383.

Fisher, D. L., & Cresswell, J. (1998). Actual and ideal principal interpersonal behaviour. *Learning Environments Research, 1*, 231-247.

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

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

Fisher, D. L., & Fraser, B. J. (1990). *School climate* (SET research information for teachers No. 2, Items 4 & 5). Melbourne, Australia: Australian Council for Educational Research.

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

Fisher, D. L., & Waldrip, B. G. (1999). Cultural Factors of Science Classroom Learning Environments, Teacher-Student Interactions and Student Outcomes. *Research in Science & Technological Education, 17*, 83-96. doi: 10.1080/0263514990170107

Francis, L. J., & Greer, J. E. (1999). Attitude toward science among secondary school pupils in Northern Ireland: Relationship with sex, age and religion. *Research in Science & Technological Education, 17*, 67-74.

Frankenberg, E. (2009). The demographic context of urban schools and districts. *Equity & Excellence in Education, 42*, 255-271.

Fraser, B. J. (1977). Selection and validation of attitude scales for curriculum evaluation. *Science Education, 61*, 317-329.

Fraser, B. J. (1978). Development of a test of science-related attitudes. *Science Education, 62*, 509-515.

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

Fraser, B. J. (1989). Twenty years of classroom climate work: Progress and prospect. *Journal of Curriculum Studies, 21*, 307-327.

Fraser, B. J. (1990). *Individualised Classroom Environment Questionnaire: Handbook*. Melbourne: Australian Council for Educational Research, ACER.

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

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

Fraser, B. J. (2002). Learning environments research: Yesterday, today and tomorrow. In S. C. Goh & M. S. Khine (Eds.), *Studies in educational learning environments: An international perspective* (pp. 1-25). Singapore: World Scientific Publishing.

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

Fraser, B. J. (2014). Classroom learning environments: Historical and contemporary perspectives. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (Vol. II, pp. 104-119). New York: Rutledge.

Fraser, B. J., Aldridge, J. M., & Adolphe, F. S. G. (2010). A cross-national study of secondary science classroom environments in Australia and Indonesia. *Research in Science Education, 40*, 551-571. doi: 10.1007/s11165-009-9133-1

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

Fraser, B. J., Anderson, G. J., & Walberg, H. J. (1982). *Assessment of learning environments: Manual for Learning Environment Inventory (LEI) and My Class Inventory (MCI) (Third version)*. Perth: Curtin University of Technology.

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

Fraser, B. J., Giddings, G. J., & McRobbie, C. J. (1992). *Assessing the climate of science laboratory classes (What Research Says to Science and Mathematics Teachers, 8).* Perth: Curtin University of Technology.

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

Fraser, B. J., & Kahle, J. B. (2007). Classroom, home and peer environment influences on student outcomes in science and mathematics: An analysis of systemic reform data. *International Journal of Science Education, 29*, 1891-1909. doi: 10.1080/09500690601167178

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

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

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

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

Fraser, B. J., & Tobin, K. G. (1991). Combining qualitative and quantitative methods in classroom environment research. In B. J. Fraser & H. J. Walberg (Eds.), *Educational environments: Evaluation, antecedents and consequences* (pp. 271-291). London: Pergamon Press.

Fraser, B. J., & Treagust, D. F. (1986). Validity and use of an instrument for assessing classroom psychosocial environment in higher education. *Higher Education, 15*(1-2), 37-57.

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

Gardner, P. L. (1975). Attitudes to science: A review. *Studies in science education, 2*(1), 1-41.

Gardner, P. L. (1995). Measuring attitudes to science: Unidimensionality and internal consistency revisited. *Research in Science Education, 25*, 283-289.

Geverdt, D., & Phan, T. (2006). *Documentation to the NCES Common Core of Data Public Elementary/Secondary School Locale Code File: School Year 2003-04. Version 1a. NCES 2006-332*.

Giddings, G. J. (1982). *Presuppositions in school science textbooks.* (Ph.D.), The University of Iowa, Ann Arbor.

Gogolin, L., & Swartz, F. (1992). A quantitative and qualitative inquiry into the attitudes toward science of nonscience college students. *Journal of Research in Science Teaching, 29*, 487-504.

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

Hacieminoglu, E., Yilmaz-Tuzun, O., & Ertepinar, H. (2011). Middle school students' attittude toward science in constructivist curroculum environment. *International Journal on New Trends in Education and Their Implications, 2*, 1-6.

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

Haertel, G. D., Walberg, H. J., & Weinstein, T. (1983). Psychological models of educational performance: A theoretical synthesis of constructs. *Review of educational research, 53*, 75-91.

Hasan, A., & Fraser, B. J. (2015). Effectiveness of teaching strategies for engaging adults who experienced childhood difficulties in learning mathematics. *Learning Environments Research, 18*, 1-13.

Heiss, E. D. (1958). Helping students develop a scientific attitude. *The Science Teacher, 25*, 371-373.

Helding, K. A., & Fraser, B. J. (2013). Effectiveness of National Board Certified (NBC) teachers in terms of classroom environment, attitudes and achievement among secondary science students. *Learning Environments Research, 16*, 1-21.

Hemphill, J. K., & Westie, C. M. (1950). The measurement of group dimensions. *The Journal of Psychology, 29*, 325-342.

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

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

Hunt, D. E. (1975). Person–environment interaction: A challenge found wanting before it was tried. *Review of educational research, 45*, 209-230.

Khalili, K. Y. (1987). A crosscultural validation of a test of science related attitudes. *Journal of Research in Science Teaching, 24*, 127-136.

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

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

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

Kim, J. O., & Mueller, C. W. (1978). *Factor analysis: Statistical methods and practical issues*. Newbury Park, CA: Sage.

Klopfer, L. E. (1971). Evaluation of learning in science. In B. S. Bloom, J. T. Hastings & G. F. Madaus (Eds.), *Handbook on formative and summative evaluation of student learning* (pp. 556-642). New York: McGraw-Hill.

Klopfer, L. E. (1976). A structure for the affective domain in relation to science education. *Science Education, 60*, 299-312.

Klopfer, L. E., & Cooley, W. W. (1963). The history of science cases for high schools in the development of student understanding of science and scientists: A report on the HOSG instruction project. *Journal of Research in Science Teaching, 1*, 33-47.

Koh, N. K., & Fraser, B. J. (2014). Learning environment associated with use of mixed mode delivery model among secondary business studies students in Singapore. *Learning Environments Research, 17*, 157-171. doi: 10.1007/s10984-013-9139-5

Koth, C. W., Bradshaw, C. P., & Leaf, P. J. (2008). A multilevel study of predictors of student perceptions of school climate: The effect of classroom-level factors. *Journal of educational psychology, 100*, 96-104.

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

Lahiri, S. (2011). Assessing the environmental attitude among pupil teachers in relation to responsible environmental behavior: A leap towards sustainable development. *Journal of Social Sciences, 7*, 33-41.

Lai, K. W. (2013). *Knowledge building with senior secondary students: a New Zealand study*. Paper presented at the 10th World Conference on Computers in Education, Toruń, Poland.

Lai, M. C. (2012). *Nature of science knowledge and scientific argumentation skills in Taiwanese college biology students.* Unpublished doctoral thesis, The Ohio State University.

Lederman, N. G. (1983). *Delineating classroom variables related to students' conceptions of the nature of science.* (Ph.D.), Syracuse University, Ann Arbor. ProQuest Dissertations & Theses Full Text database. (University Microfims No. 84-10, 728)

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*, 331-359.

Lederman, N. G., & Zeidler, D. L. (1987). Science teachers' conceptions of the nature of science: Do they really influence teaching behavior? *Science Education, 71*, 721-734.

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

Lewin, K. (1936b). Some social-psychological differences between the United States and Germany. *Journal of Personality, 4*, 265-293.

Lewin, K. (1943). Defining the field at a given time. *Psychological review, 50*, 292.

Lewin, K. (1946). Action research and minority problems. *Journal of social issues, 2*, 34-46.

Liang, J. C. (2002). *Exploring scientific creativity of eleventh-grade students in Taiwan.* Unpublished doctoral thesis, University of Texas at Austin.

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

Liu, L., & Fraser, B. J. (2013). Development and validation of an English classroom learning environment inventory and its application in China. In M. S. Khine (Ed.), *Application of Structural Equation Modeling in Educational Research and Practice* (pp. 75-89). Rotterdam: SensePublishers.

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

Long, C., & Fraser, B. J. (2015). Comparison of alternative sequencing of middle-school science curriculum: Classroom learning environment and student attitudes. *Curriculum and Teaching, 30*(1), 23-36.

Lott, K. (2002). *The evaluation of a statewide in-service and outreach program - Preliminary findings*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA.

Ly, R. K., & Malone, J. A. (2010). Teachers' perceptions of geometry instruction and the learning environment in Years 9–10 ESL classrooms *L. Sparrow, B. Kisane, & C. Hurst (Eds.), Shaping the future of mathematics education: Proceedings of the 33rd annual conference of the Mathematics Education Research Group of Australasia. Fremantle: MERGA* (pp. 367-374).

Mackay, L. D. (1971). Development of understanding about the nature of science. *Journal of Research in Science Teaching, 8*, 57-66.

Mackay, L. D., & White, R. T. (1976). *Tests of perception of scientists and self.* Melbourne: ACER.

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

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

Maor, D., & Fraser, B. J. (2005). An online questionnaire for evaluating students' and teachers' perceptions of constructivist multimedia learning environments. *Research in Science Education, 35*, 221-244.

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

Martin-Dunlop, C., & Hodum, P. (2009). Scientist–science educator collaborations: Do they improve students' understanding of the nature of science? *Journal of College Science Teaching, 39*, 66-75.

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

Mead, M., & Métraux, R. (1957). Image of the scientist among high-school students. *Science, 126*, 384-390. doi: 10.1126/science.126.3270.384

Menis, J. (1989). Attitudes towards school, chemistry and science among upper secondary chemistry students in the United States. *Research in Science & Technological Education, 7*(2), 183-190.

Meyer, G. R. (1969). *A Test of Interests*. Milton, Queensland: Jacaranda Press.

Mitchell, J. V., Jr. (1969). Education's challenge to psychology: The prediction of behavior from person-environment interactions. *Review of educational research, 39*, 695-721. doi: 10.2307/3516017

Moore, R. W., & Foy, R. L. H. (1997). The scientific attitude inventory: A revision (SAI-II). *Journal of Research in Science Teaching, 34*, 327-336.

Moore, R. W., & Sutman, F. X. (1970). The development, field test and validation of an inventory of scientific attitudes. *Journal of Research in Science Teaching, 7*, 85-94.

Moos, R. H. (1973). Conceptualizations of human environments. *American Psychologist, 28*, 652-665.

Moos, R. H. (1974). *The Social Climate Scales: An overview*. Palo Alto, CA: Consulting Psychologists Press.

Moos, R. H. (1978). A typology of junior high and high school classrooms. *American Educational Research Journal, 15*, 53-66.

Moos, R. H., & Trickett, E. J. (1974). *Classroom Environment Scale: Manual*. Palo Alto, CA: Consulting Psychologists Press.

Mukhopadhyay, R. (2013). Teachers' understanding of the nature of science and competence in teaching science–An investigation. *Educationia Confab, 2*(4), 2-11.

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

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

Myers, R. E., & Fouts, J. T. (1992). A cluster analysis of high school science classroom environments and attitude toward science. *Journal of Research in Science Teaching, 29*(9), 929-937.

Nadelson, L. S., & Sinatra, G. M. (2010). Shifting acceptance of evolution: Promising evidence of the influence of the Understanding Evolution website. *The Researcher, 23*, 13-29.

Nadelson, L. S., & Viskupic, K. (2010). Perceptions of the nature of science by geoscience students experiencing two different courses of study. *Journal of Geoscience Education, 58*, 275-285.

National Research Council (NRC). Committee on a Conceptual Framework for New K-12 Science Education Standards. (2012). *A framework for K-12 science education : Practices, crosscutting concepts, and core ideas*. Washington, D.C.: The National Academies Press.

NGSS Lead States. (2013). *Next Generation Science Standards : For states, by states*. Washington, D.C.: National Academies Press.

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

Noll, V. H. (1935). Measuring the scientific attitude. *The Journal of Abnormal and Social Psychology, 30*(2), 145-154.

Nunnally, J. (1978). *Psychometric methods*. New York: McGraw.

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

Opolot-Okurut, C. (2010). Classroom learning environment and motivation towards mathematics among secondary school students in Uganda. *Learning Environments Research, 13*, 267-277.

Ormerod, M. B. (1971). The 'Social Implications' factor in attitudes to science. *British journal of educational psychology, 41*, 335-338.

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

Oser, R., & Fraser, B. J. (2015). Effectiveness of Virtual Laboratories in Terms of Learning Environment, Attitudes and Achievement among high-school genetics students. *Curriculum and Teaching, 30*(2), 65-80.

Paige, R. M. (1979). The learning of modern culture: Formal education and psychosocial modernity in East Java, Indonesia. *International Journal of Intercultural Relations, 3*, 333-364.

Pallant, J. (2001). *SPSS survival manual. A step by step guide to data analysis using SPSS* (3rd ed.). Berkshire, UK: Open University Press.

Peer, J., & Fraser, B. J. (2015). Sex, grade-level and stream differences in learning environment and attitudes to science in Singapore primary schools. *Learning Environments Research, 18*, 143-161.

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

Pickett, L. H., & Fraser, B. J. (2009). Evaluation of a mentoring program for beginning teachers in terms of the learning environment and student outcomes in participants' school classrooms. In A. Selkirk & M. Tichenor (Eds.), *Teacher education: Policy, practice and research* (pp. 1-51). New York: Nova Science Publishing.

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

Rentoul, A. J., & Fraser, B. J. (1979). Conceptualization of enquiry-based or open classroom learning environments. *Journal of Curriculum Studies, 11*, 233-245.

Reynolds, A. J., & Walberg, H. J. (1991). A structural model of science achievement. *Journal of educational psychology, 83*, 97-107.

Richardson, R., & Brouillette, L. (2013). Historic and Ethnic Music Found to Increase Geographic Understanding: A Quasi-Experimental Study. *Journal for Learning through the Arts: A Research Journal on Arts Integration in Schools and Communities, 9,* Article. http://www.escholarship.org/uc/item/71g4x3cr

Rickards, T., den Brok, P., & Fisher, D. (2005). The Australian science teacher: A typology of teacher–student interpersonal behaviour in Australian science classes. *Learning Environments Research, 8*, 267-287.

Roberge, G. D., Gagnon, L. L., & Oddson, B. E. (2011). The ideal classroom: A comparative study of education and nursing student learning and psychosocial environmental preferences. *Institute for Learning Styles Journal, 1*, 1-16.

Robinson, E., & Fraser, B. J. (2013). Kindergarten students' and parents' perceptions of science classroom environments: Achievement and attitudes. *Learning Environments Research, 16*, 1-17.

Rubba, P. A., Harkness, W. J., & Bradford, C. S. (1996). A new scoring procedure for the Views on Science-Technology-Society instrument. *International Journal of Science Research, 18*, 387-400.

Rutherford, J., & Ahlgren, A. (1990). *Science for all Americans*. New York: Oxford University Press.

Sandman, R. S. (1973). *The development, validation, and application of a multi-dimensional mathematics attitude instrument.* Unpublished doctoral thesis, University of Minnesota. ProQuest Dissertations & Theses Full Text database.

Schibeci, R. A., & Fraser, B. J. (1987). Effects of classroom environment on science attitudes: A cross-cultural replication in Indonesia. *International Journal of Science Education, 9*, 169-186.

Schmidt, D. J. (1967). Test on understanding science: A comparison among several groups. *Journal of Research in Science Teaching, 5*, 365-366.

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

Sinclair, B. B., & Fraser, B. J. (2002). Changing classroom environments in urban middle schools. *Learning Environments Research, 5*, 301-328.

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

Smith, J. A. R. (2010). *Historical short stories and the nature of science in a high school biology class.* (MS), Unpublished masters thesis, Iowa State University.

Smith, P. R. (2013). Psychosocial learning environments and the mediating effect of personal meaning upon satisfaction with education. *Learning Environments Research, 16*, 259-280.

Sorge, C., Newsom, H. E., & Hagerty, J. J. (2000). Fun is not enough: Attitudes of Hispanic middle school students toward science and scientists. *Hispanic Journal of Behavioral Sciences, 22*, 332-345.

Soto-Rodriguez, M. (2005). *A comparison of the perceptions of classroom environment, attitudes and achievement of LEP (Limited English Proficient) and Non-LEP students in integrated science classrooms.* Unpublished doctoral thesis, Curtin University of Technology.

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

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

Taylor, B. A., & Fraser, B. J. (2013). Relationships between learning environment and mathematics anxiety. *Learning Environments Research, 16*, 297-313. doi: 10.1007/s10984-013-9134-x

Taylor, P. C., Fraser, B. J., & Fisher, D. L. (1997). Monitoring constructivist classroom learning environments. *International Journal of Educational Research, 27*, 293-302.

Teh, G. P. L., & Fraser, B. J. (1995). Associations between student outcomes and geography classroom environment. *International Research in Geographical & Environmental Education, 4*(1), 3-18.

Tisher, R. P., & Power, C. N. (1978). The learning environment associated with an Australian curriculum innovation. *Journal of Curriculum Studies, 10*, 169-184.

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

Tobin, K. G., Kahle, J. B., & Fraser, B. J. (Eds.). (1990). *Windows into science classrooms: Problems associated with higher-level cognitive learning*. London: Falmer Press.

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

Turkmen, L., & Bonnstetter, R. (1999, April). *A study of Turkish preservice science teachers' attitudes toward science and science teaching.* Paper presented at the Annual Convention of National Association of Research in Science Teaching, Boston, MA.

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

Van Petegem, K., Aelterman, A., Van Keer, H., & Rosseel, Y. (2008). The influence of student characteristics and interpersonal teacher behaviour in the classroom on student's wellbeing. *Social Indicators Research, 85*, 279-291. doi: 10.2307/27734582

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

Walberg, H. J. (1968). Structural and affective aspects of classroom climate. *Psychology in the Schools, 5*, 247-253.

Walberg, H. J. (1980). A psychological theory of educational productivity. In F. H. Farley & N. Gordon (Eds.), *Psychology and education: The state of the union* (pp. 81-108). Berkely, CA: McCutchan Publishing.

Walberg, H. J. (1986). Synthesis of research on teaching. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (Vol. 3, pp. 214-229). New York: Macmillan.

Walberg, H. J., & Anderson, G. J. (1968). Classroom climate and individual learning. *Journal of educational psychology, 59*, 414-429.

Walberg, H. J., Singh, R., & Rasher, S. P. (1977). Predictive validity of student perceptions: A cross-cultural replication. *American Educational Research Journal, 14*, 45-49.

Walker, S. L. (2006). Development and validation of the test of geography-related attitudes (ToGRA). *Journal of Geography, 105*, 175-181.

Wang, M. C., Haertel, G. D., & Walberg, H. J. (1993). What influences learning? A content analysis of review literature. *Review of educational research, 63*, 249-294.

Waxman, H. C., & Huang, S. Y. L. (1997). Classroom learning environments in urban elementary, middle, and high schools. *Learning Environments Research, 1*, 95-113.

Weinburgh, M. H. (1994, April). *Achievement, grade level, and gender as predictors of student attitudes toward science.* Paper presented at the Distinguished Research Session of the annual meeting of the American Educational Research Association, New Orleans, LA.

Welch, A. G. (2010). Using the TOSRA to assess high school students attitudes toward science after competing in the FIRST robotics competition: An exploratory study. *Eurasia Journal of Mathematics, Science & Technology Education, 6*(3), 187-197.

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

Wong, A. F. L., & Fraser, B. J. (1995). Cross-validation in Singapore of the Science Laboratory Environment Inventory. *Psychological Reports, 76*, 907-911.

Wong, A. F. L., & Fraser, B. J. (1996). Environment–attitude associations in the chemistry laboratory classroom. *Research in Science & Technological Education, 14*, 91-102. doi: 10.1080/0263514960140107

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

Wubbels, T. (1993). *Teacher–student relationships in science and mathematics classes (What Research Says to the Science and Mathematics Teacher, 11)* Perth: Curtin University of Technology.

Wubbels, T., & Brekelmans, M. (1998). The teacher factor in the social climate of the classroom. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 565-580). Dordrecht, The Netherlands: Kluwer.

Wubbels, T., & Brekelmans, M. (2012). Teacher–students relationships in the classroom. In B. J. Fraser, K. G. Tobin & C. J. McRobbie (Eds.), *Second International Handbook of Science Education* (pp. 1241-1255). New York: Springer.

Wubbels, T., Créton, H., Levy, J., & Hooymayers, H. (1993). The model for interpersonal teacher behaviour. In T. Wubbels & J. Levy (Eds.), *Do you know what you look like? Interpersonal relationships in education* (pp. 13-28). London: Falmer Press.

Yang, K. T., Wang, T. H., & Kao, Y. C. (2012). How an interactive whiteboard impacts a traditional classroom. *Education as Change, 16*, 313-332.

Yeo, S. R. (2002). *Evaluation of university physics studio learning environment: The interrelationships of students' perceptions, epistemological beliefs and cognitive outcomes.* Unpublished doctoral thesis, Curtin University of Technology, Perth. Retrieved from http://adt.curtin.edu.au/theses/available/adt-WCU20030506.115009/

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

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

Zeidan, A. (2010). The relationship between grade 11 Palestinian attitudes toward biology and their perceptions of the biology learning environment. *International Journal of Science and Mathematics Education, 8*, 783-800.

APPENDIX A

Questionnaire Assessing Classroom Environment, Attitudes and Understanding of Nature of Science

Please select the one choice that best describes your response.

INVOLVEMENT
In this science class ...

	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
I discuss ideas in class.	❏	❏	❏	❏	❏
I give my opinions during class discussions.	❏	❏	❏	❏	❏
The teacher asks me questions.	❏	❏	❏	❏	❏
My ideas and suggestions are used during classroom discussions.	❏	❏	❏	❏	❏
I ask the teacher questions.	❏	❏	❏	❏	❏
I explain my ideas to other students.	❏	❏	❏	❏	❏
Students discuss with me how to go about solving problems.	❏	❏	❏	❏	❏
I am asked to explain how I solve problems.	❏	❏	❏	❏	❏

INVESTIGATION
In this science class ...

	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
I carry out investigations to test my ideas.	❏	❏	❏	❏	❏
I am asked to think about the evidence for statements.	❏	❏	❏	❏	❏
I carry out investigations to answer questions coming from discussions.	❏	❏	❏	❏	❏
I explain the meaning of statements, diagrams, and graphs.	❏	❏	❏	❏	❏
I carry out investigations to answer questions which puzzle me.	❏	❏	❏	❏	❏
I carry out investigations to answer the teacher’s questions.	❏	❏	❏	❏	❏

I found out answers to questions by doing investigations.	❑	❑	❑	❑	❑
I solve problems by using information obtained from my own investigations.	❑	❑	❑	❑	❑

COOPERATION
In this science class ...

	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
I cooperate with other students when doing assignments.	❑	❑	❑	❑	❑
I share my books and other resources with other students when doing assignments.	❑	❑	❑	❑	❑
When I work in groups in this class, there is teamwork.	❑	❑	❑	❑	❑
I work with other students on projects in this class.	❑	❑	❑	❑	❑
I learn from other students in this class.	❑	❑	❑	❑	❑
I work with other students in this class.	❑	❑	❑	❑	❑
I cooperate with other students on class activities.	❑	❑	❑	❑	❑
Students work with me to achieve class goals.	❑	❑	❑	❑	❑

TASK ORIENTATION
In this science class ...

	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
Getting a certain amount of work done is important to me.	❑	❑	❑	❑	❑
I do as much as I set out to do.	❑	❑	❑	❑	❑
I know the goals for this class.	❑	❑	❑	❑	❑
I know what I am trying to accomplish in this class.	❑	❑	❑	❑	❑
I pay attention during this class.	❑	❑	❑	❑	❑
I am ready to start this class on time.	❑	❑	❑	❑	❑
I try to understand the work in this class.	❑	❑	❑	❑	❑
I know how much work I have to do.	❑	❑	❑	❑	❑

SOCIAL IMPLICATIONS OF SCIENCE

	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
Money spent on science is worth spending.	❏	❏	❏	❏	❏
Public money spent on science in the last few years has been spent wisely.	❏	❏	❏	❏	❏
The government should spend more money on scientific research.	❏	❏	❏	❏	❏
Science helps to make life better.	❏	❏	❏	❏	❏
Science can help to make the world a better place in the future.	❏	❏	❏	❏	❏
Scientific discoveries are doing more good than harm.	❏	❏	❏	❏	❏

NORMALITY OF SCIENTISTS

	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
Scientists are about as fit and healthy as other people.	❏	❏	❏	❏	❏
Scientists like sports as much as other people do.	❏	❏	❏	❏	❏
Scientists can have a normal family life.	❏	❏	❏	❏	❏
Scientists are just as interested in art and music as other people are.	❏	❏	❏	❏	❏
If you met a scientist, he or she would probably look like anyone else you might meet.	❏	❏	❏	❏	❏
Scientists are as friendly as other people.	❏	❏	❏	❏	❏

TENTATIVE NATURE OF SCIENCE

	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
Scientists are interested in better explanations of things.	❏	❏	❏	❏	❏
Scientific ideas can be changed.	❏	❏	❏	❏	❏
Scientists believe that little is known for sure.	❏	❏	❏	❏	❏
Scientific research will face change and old theories will be replaced.	❏	❏	❏	❏	❏
Scientific advances cannot be made in a short time.	❏	❏	❏	❏	❏
Scientific theory will advance and improve with the addition of new information.	❏	❏	❏	❏	❏

EMPIRICAL BASIS OF SCIENCE

	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
Scientists cannot always find the answers to their questions.	❏	❏	❏	❏	❏
Some questions cannot be answered by science.	❏	❏	❏	❏	❏
The senses (e.g. sight, touch, hearing, taste, and smell) are important in science.	❏	❏	❏	❏	❏
Two theories can provide explanations from different viewpoints.	❏	❏	❏	❏	❏
Scientists tend to accept the theory they are more familiar with.	❏	❏	❏	❏	❏
Scientists prefer simpler theories to complex ones.	❏	❏	❏	❏	❏

SCIENTIFIC METHOD

	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
Scientific questions are answered by observing things.	❏	❏	❏	❏	❏
Good scientists are willing to change their ideas.	❏	❏	❏	❏	❏
Scientists must report exactly what they observe.	❏	❏	❏	❏	❏
The scientific method leads to valid, clear, logical, and accurate results.	❏	❏	❏	❏	❏
Most scientists use the scientific method because it is logical.	❏	❏	❏	❏	❏
There is no fixed scientific method.	❏	❏	❏	❏	❏

Your School:

Your Teacher, Subject, and Period:

Your Name (Remember, your information will be coded and will be kept confidential):

The Involvement, Investigation, Cooperation and Task Orientation scales are based on the What Is Happening In this Class? (WIHIC, Aldridge, Fraser & Huang, 1999), the Social Implications of Science and Normality of Scientists scales are based on the Test of Science Related Attitudes (TOSRA, Fraser, 1981), and the Tentative Nature of Science and Empirical Basis of Science scales are based on the Scientific Attitudes Scale (SAI, Moore & Sutman, 1970) and Views on Science and Education (VOSE, Aikenhead & Ryan, 1992).