Science and Mathematics Education Centre

Evaluation of Classroom Performance System (CPS) Technology Integration in Terms of Classroom Environment and Attitudes

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Declaration

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

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Date: December 2011

Abstract

The push for technology in education might not be as successful as some 21st century policy makers might expect. Numerous researchers have failed to find any positive outcomes following the integration of technology into education. This study compared classrooms in which Classroom Performance System (CPS) technology had been integrated with non-CPS classrooms in terms of the classroom learning environment and students' attitudes toward science. Student perceptions of the learning environment were assessed with a modified version of the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) and student attitudes were assessed with the Attitude and Efficacy Questionnaire. These instruments were administered to a sample of 971 students as a pretest and 389 students as a posttest with 17 different teachers, of students in grades 9 through 12, from a large school district in New York State.

The gender breakdown for this sample consisted of 179 males and 210 females, and there were 178 CPS students and 211 non-CPS students. The differential effectiveness of CPS technology for different genders was also investigated.

Simple correlation and multiple regression analyses were used to examine the relationships between student perceptions of the classroom environment and the student attitudes. The analysis involved a two-way MANOVA with the TROFLEI scales and attitude scales as the dependent variables. The two independent variables were the instructional method (CPS and non-CPS) and student gender. Differential effectiveness was considered to exist if there was a significant instruction x gender interaction for a particular dependent variable.

Because the MANOVA using the Wilks' lambda criterion showed significant differences for the set of dependent variables as a whole, the univariate ANOVA was interpreted for each individual environment and attitude scale. The average item mean, average standard deviation, *F* values and effect sizes from MANOVA were calculated for each of the scales of the TROFLEI and Attitude and Efficacy Questionnaire. Overall, students in the CPS class appear to have benefited somewhat from the CPS technology integration. To examine the magnitudes of the differences between instructional group, as well as their statistical significance, effect sizes were calculated in terms of the differences in means divided by the pooled standard deviation. The effect size for Equity was relatively small with a value of 0.21 standard deviations. This result suggests differences in students' perceptions of Equity in the classroom learning environment between students using CPS clickers and those students that were not using the clickers.

Although gender differences in learning environment perceptions and attitudes were not the focus of the research questions, some statistically significant results were revealed. Results show that both Task Orientation and Attitude to Subject yielded significant gender differences. These effect sizes indicate gender differences that are small in magnitude. Relative to males, females liked science more and perceived that their classes were more task oriented.

The results from this study revealed a significant instruction-by-gender interaction for Computer Usage. For the experimental group, males perceived greater Computer Usage than females. However, for the control group, females perceived greater Computer Usage.

Data analyses supported the TROFLEI's and Attitude and Efficacy Questionnaire's factorial validity, internal consistency reliability, and ability to differentiate between the perceptions of students in different classrooms. All TROFLEI scales correlated significantly and positively with student attitudes.

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Abbreviations

CAS	*Computer Attitudes Survey*
CES	*Classroom Environment Scale*
CLES	*Constructivist Learning Environment Survey*
COLES	*Constructivist-Orientated Learning Environment Survey*
CPS	*Classroom Performance Systems*
CUCEI	*College and University Classroom Environment Inventory*
HLM	*Hierarchical Linear Modeling*
ICE	*Elementary and Middle School Inventory of Classroom Environments*
ICEQ	*Individualised Learning Environment Questionnaire*
ICT	*Information and Communication Technology*
LEI	*Learning Environment Inventory*
MCI	*My Class Inventory*
MJSES	*Morgan-Jinks Student Efficacy Scale*
NBC	*National Board Certified*
QOCRA	*Questionnaire on Chemistry-Related Attitudes*
QTI	*Questionnaire on Teacher Interaction*
SAI	*Scientific Attitude Inventory*
SLEI	*Science Laboratory Environment Inventory*
SRS	*Student Response Systems*
TOSRA	*Test of Science-Related Attitudes*
TROFLEI	*Technology-Rich Outcomes-Focused Learning Environments Inventory*
WIHIC	*What Is Happening In this Class?* questionnaire

Table of Contents

List of Tables

List of Figures

Chapter 1
Introduction

1.1 Introduction

Research into the effectiveness of technology integration, in terms of the science classroom learning environment and student attitudes, is needed because technology could potentially change learning environments and attitudes. In order to understand any changes created by, and the advantages and disadvantages of technology, the comprehensive evaluation reported in this thesis was undertaken.

This chapter provides an introduction for the current study. The rationale for the study is described (Section 1.2) and the research questions are stated (Section 1.3). The theoretical framework that supports this study is introduced (Section 1.4), the research methods are briefly summarized (Section 1.5), and the significance of this work is discussed (Section 1.6) as well. Because the study was conducted in New York State, an overview of science education in New York is provided (Section 1.7). The chapter concludes with an overview of the thesis (Section 1.8).

1.2 Rationale for the Study

If technology integration is as effective as many educators think it is, research evidence to support its use would provide educators with the empirical backing to continue technology integration and provide the resources that teachers need to ensure that technology is readily available to all students. However, if research evidence does not support the effectiveness of technology integration, then a revaluation and redirection of many policies encouraging technology use in daily classroom activities might be needed. One of the appeals of technology in the classroom is the availability of information to students, who are accustomed to rapid feedback in many aspects of life.

The educational systems of the industrialized world seem to lag behind the real world in timeliness of information. Although parental contact has become easier and faster through the use of email and computer-generated reports for grading, the traditional classroom setting often leaves students waiting for feedback on their formal assessment grades. Students are often left wondering if they understood the content until they receive their assignment/examination grade or their grade for the term. Teachers with 100+ students find it difficult to give immediate feedback on assignments; at the very least, the student is waiting until the next day and is already mentally removed from the learning process that took place the day before. There is plenty of attention paid to technology integration in educational reform starting at the top from educational mandates and all the way down to individual teachers; however, research suggests that many of the assumptions that are being made about the effectiveness of technology could be unrealistic.

The push for technology in education might not be as successful as some 21st century policy makers might expect. Numerous researchers have failed to find positive outcomes from the integration of technology in education (2001; Harwell, Gunter, Montgomery, Shelton, & West, 2001; Yeo, Loss, Zadnik, Harrison, & Treagust, 2004).

In 2001, Cuban conducted a study in Silicon Valley schools that revealed that over 90% of teachers do not use computers in the classroom at least once a week. According to Cuban, the research lacks evidence to support using information technologies to improve student achievement and therefore does not provide enough evidence supporting the expectations of policymakers that using technology improves education. Cuban contends that resources should be allocated to professional development and support for teachers to optimize existing technologies instead of towards new technologies (Cuban, 2001).

Harwell, Gunter, Montgomery, Shelton and West (2001) used the Constructivist Learning Environment Survey with a team of teachers in mathematics, science, language arts and social studies and their 65 sixth-grade students. Professional development was provided in Internet use and the team integrated Internet-based activities into daily lesson plans. Comparisons of pretest and posttest responses revealed no significant changes in student perceptions of the learning environment over the duration of the academic year. The teachers in the study used this information to align their classrooms with constructivist pedagogy facilitated by technology implementation; technology was used to enhance changes in pedagogy, but it did not lead to improved learning environments solely on its own (Harwell et al., 2001).

Yeo, Loss, Zadnik, Harrison and Treagust (2004) conducted a study involving interactive physics multimedia. These authors discussed how students did not learn the targeted physics concepts and suggested that students first needed to be taught how to use the program and devise strategies to self-assess learning through reflective points to understand the targeted concepts (Yeo et al., 2004).

Classroom Performance System (CPS) technology is a program and set of remote controls that are used in an effort to provide instantaneous feedback to students, as well as to the teacher, on the degree of success of students and classes as a whole. Questions are presented to the students as a class and each individual student is equipped with a remote control and instructed to answer the question and to send his or her response to the computer (this is all accomplished with the click of a button). Student data are then organized into a chart format and as postings on the screen for the class to see. The teacher can then immediately address any issues with the understanding and students can convey their misunderstandings because this process happens on a question-by-question basis. Assessment is then easily embedded into daily lessons and the instantaneous feedback gives students real-time information about the understanding of content presented in the course.

The use of Student Response System (SRS) technologies, including CPS, have had mixed success in past research. Most researchers who did not find positive outcomes associated with SRS technologies integration have identified pedagogy as a missing link to the success of the technology. Using SRS was found to be successful when it was used to facilitate changes in pedagogy; research supports the change of pedagogy as the key to improved learning with technology used as a facilitator (Draper, 1998; Draper & Brown, 2004; Judson & Sawada, 2002). Crouch and Mazur (2001) agree with Draper and Brown in that using voting systems (SRS technology) in conjunction with ‘peer instruction’ led to improvements in standardized test results; in this study, the focus was on the pedagogy behind ‘peer instruction’ as facilitated by voting systems.

In a discussion of response system technologies research dating back to the 1960s, Judson and Sawada (2002) contest whether pedagogical changes are the reasons for positive learning outcomes, and not the technology in and of itself. Penuel, Boscardin, Masyn and Crawford’s (2007) survey of the degree to which teachers use student response system technologies revealed that teachers who used response system technology most frequently and who exhibited the most diversity in strategies used were the most likely to have received training (Penuel et al., 2007).

The current study was framed in the field of learning environments because it involved the perceptions of students from two distinct learning environments (CPS and non-CPS). The effectiveness of integration of CPS technology was investigated in terms of both the classroom environment and attitudes. If it is true that technology implementation is only effective when there is a focus on changes in pedagogy, then professional development on existing technology should be the focus of future allocations of resources for technology.

1.3 Research Questions

To examine whether the instruments used in the study were valid and reliable, the first research question was written:

Research Question 1:

> *Are the following questionnaires valid when used with a sample from a large school district in New York State:*
>
> *(a) a modified version of the* Technology-Rich Outcomes-Focused Learning Environments Inventory (TROFLEI)*?*
>
> *(b)* Attitude and Efficacy Questionnaire*?*

To examine whether a relationship exists between students’ perceptions of the classroom learning environment and student attitudes, the second research question was written:

Research Question 2:

Are there associations between classroom learning environment and student attitudes toward science?

To examine the effectiveness of Classroom Performance System (CPS) technology integration, the third research question was written:

Research Question 3:

Is Classroom Performance System (CPS) technology integration effective in terms of:

(a) classroom environment?
(b) student attitudes toward science?

To investigate whether Classroom Performance System (CPS) technology integration is differentially effective for males and females, the fourth research question was written:

Research Question 4:

Is Classroom Performance System (CPS) technology integration differentially effective for males and females in terms of:

(a) classroom learning environment?
(b) student attitudes toward science?

1.4 Theoretical Framework

Classroom Performance System (CPS) technology integration has yielded positive results in some past research. Blood and Neel (2008) reported higher scores on weekly quizzes and increased engagement during lectures when CPS-like technology was used. Three additional studies reported improvement in engagement and achievement (Draper & Brown, 2004; Hake, 1998; Kennedy & Cuts, 2005). According to Blood and Neel (2008), with students reporting enjoyment while using the system and perceiving that the technology assisted their learning. Improvements in both engagement and achievement were obtained without major changes in pedagogy (Dufresne, Gerace, Leonard, Mestre, & Wenk, 1996). However, the studies that reported that CPS technology integration promoted improved classrooms are counterbalanced by other studies that have failed to find any positive outcomes.

Although there have been numerous educational technologies introduced to facilitate learning in the classroom, technologies such as CPS have not been universally adopted. Teachers can ask students to answer questions and gain instantaneous feedback, which can be immediately used to change the course of a lesson and to ensure all students are actively engaged in discussions. CPS-like technologies are now more affordable, have more features and are more available. Research evidence about their educational value would help educators to make more informed choices regarding the investment into such technology. An evaluation of Classroom Performance System (CPS) technology integration in terms of classroom environment and attitudes was the focus of the current study.

The current study drew on the field of learning environments. By utilizing CPS technology in classrooms of the experimental groups, two different high-school science classroom learning environments are established; classrooms that use CPS and classrooms that do not use CPS. Because perceptions of the classroom learning environment have been consistently related to learner outcomes in past research, a close examination of the differing perceptions of students was in order (Aldridge, Fraser, & Sebela, 2004). Furthermore, if technology were differentially effective for males and females, research findings would help educators to focus on differentiating instruction for males and females. Positive perceptions of the classroom typically are linked to higher achievement and better attitudes (Chionh & Fraser, 2009).

Learning environment instruments can be used to collect quantitative data for the evaluation of a variety of educational innovations, including CPS technology integration. Over the past 40 years, the evaluation of educational innovations has been a common focus in learning environments research. During the late 1960s, the Learning Environment Inventory (LEI) was developed and used in the evaluation of Harvard Project Physics (Fraser, Anderson, & Walberg, 1982; Walberg & Anderson, 1968). Later, in a large study of about 3,000 students in tenth-grade, the LEI was used to survey student perceptions in India (Walberg, Singh, & Rasher, 1977).

During the same time period, Moos used social climate scales in a variety of types of institutions and ultimately developed the Classroom Environment Scale (CES) for use in schools (Moos & Trickett, 1974).

Since the work of Walberg and Moos, learning environment instruments have been used to evaluate educational innovations in the learning environment. Khoo and Fraser (2008) used the What Is Happening In this Class? (WIHIC) to evaluate the classroom learning environment of computer application courses for adults in Singapore. The WIHIC was also used by Wolf and Fraser (2008) to evaluate inquiry instruction in the science classroom in New York.

Studies that are more contemporary have employed the WIHIC and Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) to assess educational innovations. The TROFLEI was used to monitor and evaluate a new senior high school in Australia that concentrates on outcomes-focused educational programs (Aldridge & Fraser, 2008, 2011). The WIHIC was used by Pickett and Fraser (2009) in a study that monitored changes in the learning environment in beginning teachers' classrooms during a two-year mentoring program.

The present study was based in the field of learning environments and involved differences in the perceptions of students using CPS technology integration and those students who did not use the technology. CPS technology is an educational innovation that was evaluated in the current study using a modified version of the TROFLEI to compare two groups of students.

An Attitude and Efficacy Questionnaire was used in the current study for two reasons: to evaluate the effectiveness of CPS technology integration in terms of students' attitudes; and to investigate the associations between the classroom learning environment and student attitudes toward science. The three scales in the Attitude and Efficacy Questionnaire, Attitude to Subject, Attitude to Computers and Academic Efficacy, were developed by Aldridge and Fraser (2008). The same response alternatives as the TROFLEI are used in the Attitude and Efficacy Questionnaire (Almost Never, Seldom, Sometimes, Often and Almost Always).

Both instruments were chosen because they have shown sound internal consistency reliability, factorial validity and discriminant validity in past research (Aldridge &

Fraser, 2008). The validity of the chosen questionnaires is discussed further in Section 3.4.

1.5 Research Methods

In the current study, a modified version of the Technology-Rich Outcomes-Focused Learning Environments Inventory (TROFLEI) was used to assess student perceptions of the science classroom learning environment and the Attitude and Efficacy Questionnaire to assess student attitudes (Aldridge & Fraser, 2008) . In the first phase of the research, a pilot study involved assessing the readability of the modified TROFLEI and Attitude and Efficacy Questionnaire among high-school students, as well as identifying and resolving any issues in the electronic administration of the survey.

The second phase of this research study was the main study when the modified TROFLEI and Attitude and Efficacy Questionnaire were administered to samples of 971 students as a pretest and of 389 students as a posttest. Data from the instruments in the main study were used to answer the four research questions concerning:

1. Whether the instruments used in the study were valid and reliable;
2. Whether a relationship exists between students' perceptions of the classroom learning environment and student attitudes;
3. The effectiveness of CPS technology integration; and
4. Whether CPS technology integration is differentially effective for males and females.

The main study included two distinct groups of students: an experimental group and a control group. The experimental group had Classroom Performance Systems (CPS) technology integrated into daily lessons in their science classes, whereas the control group were taught the same curriculum units without using CPS. Having two groups permitted comparisons between those classes integrating CPS clickers and those that were not integrating CPS clickers; two different types of learning environments were established by the teachers depending on whether they integrated CPS or not.

1.6 Significance

The current study is significant within the field of learning environments because it represents the first evaluation of the use of CPS that employed learning environment dimensions as criteria of effectiveness. As well, another contribution is that the Technology-Rich Outcomes-Focussed Learning Environment Inventory (TROFLEI) and Attitude and Efficacy Questionnaire were cross-validated when used with high-school science students in New York.

The school district identifies assessment, diagnosis, and prescription as major instructional priorities. Data that indicate whether or not Classroom Performance System (CPS) technology integration has positive effects on the science classroom learning environment and student attitudes are important for the district when considering whether resources should be allocated to purchasing such technology. Using the technology to embed assessments might aid teachers and students in diagnosing lapses in understanding. But more information about the effectiveness of CPS technology integration would be useful for guiding decisions about purchasing more technology or allocating some resources for teacher professional development focused on the effective implementation of the CPS technology.

School districts are spending unprecedented amounts of funding on upgrading buildings and classrooms with the latest technologies, but many of the technologies have been neither fully integrated into each classroom nor rigorously evaluated. It is important to understand the impact of technologies such as CPS in terms of the classroom learning environment and student attitudes. Results from this study might lead to further investigation of response system technologies and possibly influence decisions about whether to purchase and integrate such technologies into daily lessons. Research on the impact of using technology for embedding assessment and timely feedback into daily lessons is needed.

The current study also was significant because it investigated the differential effectiveness of the implementation of CPS technology for males and females. Teachers need to be aware of how both males and females perceive technology integration. Even though teachers might assume that they are being equitable in their treatment of both males and females, student perceptions can differ. By taking cognizance of findings from the current study, teachers could be guided in being more equitable in their teaching methods.

1.7 Context of the Study: An Example of Science Education in One New York School District

New York State assesses high-school students at the completion of each core science subject. Each school district in New York determines its own sequencing of courses and each teacher has educational license to pace and teach the state curriculum according to his or her own personal style.

The high school in which the study took place comprises grades 9–12. Students generally take a biology course called Living Environment, Earth Science, Chemistry and then Physics. Based on the timing of the study during the school year, cells and photosynthesis and cellular respiration were chosen as the units for the biology courses with CPS integration, whereas astronomy and weather were chosen as the units in earth science. Students in the experimental groups were taught the same course content with CPS technology integration as those students in the control group without the CPS technology integration.

The data were collected from students in 22 sections of biology and 35 sections of earth science. The experimental group integrating CPS technology consisted of 7 sections of biology and 13 sections of earth science.

1.8 Overview of the Thesis

The conceptualization, implementation, and findings of the study are presented in five chapters. Chapter 1 introduced the background (Section 1.1), rationale (Section 1.2), research questions (Section 1.3), theoretical framework (Section 1.4), basic research methods (Section 1.5), significance (Section 1.6), and educational context (Section 1.7), as well as providing an overview of the thesis (Section 1.81.8).

Chapter 2 is a review of literature related to the current study, arranged into four main sections. The field of learning environments, including a historical perspective and many of the questionnaires found to be reliable and valid, is reviewed (Section 2.2). Assessment of student attitudes is also reviewed (Section 2.3). Literature reporting past research involving learning environments, especially evaluations of educational innovations and the investigation of associations between learning environments and student outcomes, is reviewed (Section 2.4). Literature related to technology use in the classroom, as well as the need for its evaluation of the differential effectiveness of Classroom Performance Systems (CPS) for males and females, is also reviewed (Section 2.5).

Chapter 3 provides details of the research methods and samples used in the current study. The research questions that are the focus of the current study are repeated (Section 3.2) and the research design is discussed (Section 3.3). The instruments that were used to assess the learning environment (TROFLEI) and student attitudes (Attitude and Efficacy Questionnaire) in the study are described in detail (Section 3.4). The two phases in which data were collected (the pilot study and the main study) are described (Section 3.5). The students selected for the study were a part of either the experimental (CPS) or control (non-CPS) group and were asked to respond to both a pretest and posttest administration of the survey as described in detail (Section 3.6). Methods of administration of the survey (Section 3.7) and data collection (Section 3.8), as well as data analysis (Section 3.9), are discussed.

Chapter 4 provides a details about the data analyses and results which relate to the four research questions: the validity and reliability of the instruments used (Section 4.2); associations between learning environment and attitudes (Section 4.3); the effectiveness of CPS technology integration in terms of classroom learning environment and student attitudes towards science (Section 4.4); and the differential effectiveness of using CPS for males and females (Section 4.4).

Chapter 5 offers a detailed discussion of the findings for each research question (Section 5.2). A discussion of the educational implications of the study (Section 5.3), its limitations (Section 5.4) and some recommendations for future research are also proposed (Section 5.5).

Appendix A at the end of the thesis contains the two instruments that were administered to students in the current study: a modified version of the TROFLEI and the Attitude and Efficacy Questionnaire.

Chapter 2
Literature Review

2.1 Introduction

This chapter reviews literature related to the present study which investigated the effectiveness of Classroom Performance Systems (CPS) technology integration in terms of students' perceptions of the learning environment and attitudes toward science classes, associations between learning environment and attitude scales, and the differential effectiveness of this technology integration for different genders.

Literature from the field of learning environments, in which this study was located, is reviewed in Section 2.2. This includes a historical perspective on the field (Section 2.2.1) and an overview of various learning environment questionnaires (Section 2.2.2.). Literature on the historical progression of research related to student attitudes and factors related to student attitudes is reviewed in Section 2.3. Section 2.4 reviews past research involving the use of learning environment questionnaires.

The main focus of the study was an evaluation of Classroom Performance Systems (CPS) technology integration in the classroom. Therefore, Section 2.5 discusses the need for evaluation of technology in the classroom including: CPS and CPS-like technologies (Section 2.5.1); and differential effectiveness of CPS technology integration for different genders (Section 2.5.2).

2.2 Field of Learning Environments

Learning environments has been an expanding field of research during recent decades. Section 2.2 reviews literature related to the historical progression of the field and the chronology of the development of numerous questionnaires.

2.2.1 Background and Historical Perspective

Everyone must learn! The ability to survive and prosper is directly related to how well an individual learns from experiences that are lived or conveyed to them.

Because formal education is a privilege that most individuals take advantage of, educators can make the biggest impact on communities and society as a whole. Educators have the most contact time with young, developing citizens and are the greatest hope for creating and maintaining societies of people who have the values and knowledge to maintain and excel in the communities where they live. Educational experiences are important! The quality of classroom life determines many of the outcomes from education; as a result of positive classroom experiences, citizens develop concern for community and others and commitment to their objectives (2001, p. 2). The content of any curriculum is not going to benefit the class as much as the experiences and climate of the classroom. Perhaps Ginott (1971, p. 13) summarizes the role of the teacher in the learning environment best:

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

With all of this in mind, here's the problem: most educators devote the majority of their time and energy to content and curriculum and pay little attention to improving the learning environment. According to Fraser (2001, p. 2), the narrow focus on achievement can lead to the destruction of the human qualities that education experiences bring to students. In fact, there is an overwhelming amount of research that indicates that the learning environment strongly influences student achievement. Research indicates that energy spent on improving the learning environment is likely to lead to improved student outcomes (Fraser, 2007). A better understanding of learning environments can lead to improvements in classroom environments and therefore student outcomes. Learning environment research has led to the creation and validation of numerous questionnaires.

The field of learning environment research has come a long way in that last few decades; progress in this field can be attributed mainly to Fraser, Walberg, Moos and colleagues. Tobin (2000) attributes this progress to Fraser's exploration of the psychosocial dimensions using a myriad array of learning environment questionnaires. Energy expended on improving the learning environment is worth it. Many of the research studies conducted in the field of learning environments have found a positive association between the learning environment and student achievement. Teachers should spend time assessing their own classrooms in an effort to improve the learning environment and hopefully improve achievement levels as well. Sometimes the significance of an individual's educational experience is lost in the era of standardized testing and measurements of student achievement; learning environments not only have an impact on a student's ability to achieve, but also on students' attitudes towards learning and improving themselves for the duration of their lifetime. Fortunately, the field has a variety of widely-applicable questionnaires that were designed to assess student perceptions of their learning environments (Fraser, 2002) and which are reviewed comprehensively in Section 2.2.2.

2.2.2 Learning Environment Questionnaires

There is a wide array of instruments that are readily available to educators for use in assessing aspects of different learning environments. These instruments have been validated and can be used easily. There are nine historically-important and contemporary instruments that are used in learning environments research and that are reviewed below in Sections 2.2.2.1 to 2.2.2.9: Learning Environment Inventory (LEI), Classroom Environment Scale (CES), Individualized Classroom Environment Questionnaire (ICEQ), My Class Inventory (MCI), College and University Classroom Environment Inventory (CUCEI), Questionnaire on Teacher Interaction (QTI), Science Laboratory Environment Inventory (SLEI), Constructivist Learning Environment Survey (CLES), and What Is Happening In this Class? (WIHIC) (Fraser, 1998a). In addition, literature related to the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) is reviewed in a separate section (Section 2.2.2.10) because it was selected for use in the current study.

2.2.2.1 Learning Environment Inventory (LEI)

The Learning Environment Inventory (LEI) was developed during the late 1960s in relation to the evaluation of Harvard Project Physics (Fraser et al., 1982; Walberg &

Anderson, 1968). This instrument was designed for teacher-centered classrooms and contains 105 statements for students to respond to. There are seven statements per scale and the student has four response choices: Strongly Disagree, Disagree, Agree, or Strongly Agree. The scales are: Cohesiveness, Friction, Favoritism, Cliqueness, Satisfaction, Apathy, Speed, Difficulty, Competitiveness, Diversity, Formality, Material Environment, Goal Direction, Disorganization and Democracy. In a large study of about 3,000 tenth-grade students in science and social studies classes, the LEI was used in a Hindi language to survey student perceptions (Walberg et al., 1977). Student perceptions were positively linked to achievement beyond what could be attributed to ability level (Walberg & Anderson, 1968). The LEI was one of the first instruments to assess the environment and its association with a student's learning experience.

2.2.2.2 Classroom Environment Scale (CES)

The Classroom Environment Scale (CES) grew from a program of research assessing the social climates of a multitude of different human environments that foster interpersonal relationships (Moos & Trickett, 1974). Some of the environments include: psychiatric hospital, university residences, prisons, and work milieus (Moos & Trickett, 1974). The CES is a 90-item questionnaire that assesses Involvement, Affiliation, Teacher Support, Task Orientation, Competition, Order and Organization, Rule Clarity, Teacher Control and Innovation. The CES assesses student perceptions of interactions in the learning environment (Fisher & Fraser, 1983; Moos, 1979; Moos & Trickett, 1974, 1987).

2.2.2.3 Individualized Classroom Environment Questionnaire (ICEQ)

The Individualized Classroom Environment Questionnaire (ICEQ) assesses the extent to which the learning environment is differentiated. The ICEQ contains 50 items that assess the five scales of Personalization, Participation, Independence, Investigation and Differentiation. Each of the items has five possible frequency responses: Almost Never, Seldom, Sometimes, Often or Very Often (Fraser, 1990). This instrument was developed to fill a need in learning environments research by assessing how individualized students perceive the learning environment to be. The ICEQ assesses the level of individualization occurring in the classroom setting, especially students' perceptions of the differentiated experiences created by the teacher as a response to each individual's needs.

2.2.2.4 My Class Inventory (MCI)

The My Class Inventory (MCI) was developed as a simplified version of the LEI. Although the MCI was designed for elementary-school students, it also can be used with other students who have limited reading skills. This instrument contains 38 items that assess Cohesiveness, Friction, Satisfaction, Difficulty and Competitiveness. Fraser and O'Brien (1985) further simplified the MCI to a 25-item short version, the My Class Inventory – Short Form (MCI – SF). Although the original MCI had two response alternatives (Yes or No), Goh and Fraser (1998) used three response alternatives (Seldom, Sometimes and Most of the Time) in research involving the use of the MCI in Singapore.

In a study of 1,565 students from 81 classes in 15 government secondary schools in Brunei Darussalam, the MCI was refined to a three-scale version assessing Cohesiveness, Difficulty and Competition. Majeed, Fraser and Aldridge (2002) validated this version for use in Brunei Darussalam in terms of factor structure, internal consistency reliability and ability to differentiate between classrooms. The questionnaire was used to describe the average classroom environment and to investigate associations between the classroom environment and student satisfaction. The study revealed positive associations between Satisfaction and the classroom learning environment. Student Cohesiveness had the strongest positive association with Satisfaction, and Difficulty was significantly associated with dissatisfaction (Majeed et al., 2002).

Leaders in the school counseling profession have pushed for additional counselor accountability and research on the effectiveness of comprehensive school counseling programs. The MCI – SF has demonstrated reliability and validity when used with American elementary students. In order for the counselors to use the MCI – SF, the questionnaire needed to be tested for internal consistency and factorial validity when used with upper-elementary students. The study involved more than 2,800 grade 3 – 5 students in a large urban school district in Washington State. The results led to further modifications to the MCI – SF, including reduction to only 18 items from the

Satisfaction, Cohesion, Competitiveness and Friction scales, to form an instrument that could be used as an accountability tool for elementary comprehensive school counseling programs (Sink & Spencer, 2005).

The MCI was used with 588 upper-elementary students in Texas to evaluate the effectiveness using a textbook, science kits or a combination of the two (Scott Houston, Fraser, & Ledbetter, 2008). The study supported a four-factor structure for the MCI consisting of Friction, Competition, Cohesiveness and Satisfaction. Student Satisfaction was higher among students using science kits only. Student Cohesiveness was lowest among students using only textbooks and highest among students using only science kits. This study with the MCI supported the usefulness of science kits for promoting student satisfaction, and cohesiveness in the science classroom (Scott Houston et al., 2008).

2.2.2.5 College and University Classroom Environment Inventory (CUCEI)

The College and University Classroom Environment Inventory (CUCEI) is a 49-item survey focused on Personalization, Involvement, Student Cohesiveness, Satisfaction, Task Orientation, Innovation and Individualization at the college/university level. Each item has four possible responses: Strongly Agree, Agree, Disagree or Strongly Disagree. The survey was designed to assess the learning environment in the smaller class of about 30 students at the college level (Fraser & Treagust, 1986; Fraser, Treagust, & Dennis, 1986). Logan, Crump and Rennie (2006) used the CUCEI in research involving working in computing classrooms in New Zealand and found that its psychometric performance was not ideal.

2.2.2.6 Questionnaire on Teacher Interaction (QTI)

The Questionnaire on Teacher Interaction (QTI) draws upon a theoretical model of proximity and influence to assess behavior aspects of a teacher as perceived by the student: Helpful/Friendly, Understanding, Dissatisfied, Admonishing, Leadership, Student Responsibility and Freedom, Uncertain and Strict. There are five possible responses ranging from Never to Always. The QTI assesses the behaviors of teachers as perceived by the student (Wubbels, 1993).

A Korean version of the QTI displayed sound internal consistency reliability and differentiated between the perceptions of students from different classrooms in a study of 543 Korean students (Kim, Fisher, & Fraser, 2000). The interpersonal behavior of the science teachers was shown to be directive with less leadership, helping/friendly and understanding behaviors than for teachers in other studies conducted in Australia and Singapore (Rickards, Fisher, Goh, & Wong, 1997). There were also significant gender differences in perceptions of teacher behavior, with boys perceiving their teachers' interpersonal behavior more favorably (Kim et al., 2000).

A Korean version of the QTI was again used in a study of 439 students to examine the current status of Korean senior high school science classroom learning environments. The QTI was translated and cross-validated. Korean students in this study viewed their teachers as directive and controlling. The relationship between teacher and pupil seemed to reflect the 'youth-elder relationship' in a society that involves teachers directing obedient students (S. S. U. Lee, Fraser, & Fisher, 2003).

An elementary version of the QTI was translated into standard Malay in a study of 3,104 students and was found to be valid and reliable with Malay-speaking elementary-school students in Brunei Darusssalam. The study involved validating the instrument in Malay and comparing Bruneian student responses with those of students from other countries. Future studies in many other countries are now possible because of the availability of a Malay translation of the QTI (Scott & Fisher, 2004).

When the QTI was used in a study among 497 secondary-school chemistry students in Singapore, it exhibited satisfactory internal consistency reliability. The study showed that the interpersonal behavior of teachers has an impact on the attitudes of students towards chemistry (Quek, Wong, & Fraser, 2005).

The QTI was also used in a study that examined both interpersonal teacher behavior and classroom climate among 1,512 primary mathematics students in Singapore. The questionnaire was validated for future use in research involving primary students. Associations between classroom learning environment and student outcomes were found. Gender differences were also observed; girls viewed their learning environments more favorably while boys generally achieved more highly (Goh & Fraser, 1998).

Fraser, Aldridge and Soerjaningsih (2010) reported a study focusing on perceived instructor-student interpersonal behavior and its effect on achievement and attitudes among Indonesian students at the university level. The research involved 422 university students and the translation, validation and use of an Indonesian version of the questionnaire. The QTI exhibited high internal consistency reliability and could differentiate between the responses from students in different classrooms. The study also revealed positive associations between student attitudes and more favorable teacher-student interactions (Fraser, Aldridge, & Soerjaningsih, 2010).

The QTI has been translated and validated in over a dozen languages and research using the instrument has replicated the advantages of positive relationships between students and teachers (Fraser & Walberg, 2005).

2.2.2.7 Science Laboratory Environment Inventory (SLEI)

The Science Laboratory Environment Inventory (SLEI) assesses the unique environment of science instruction in a laboratory setting. This 35-item instrument has the five scales of Student Cohesiveness, Open-Endedness, Integration, Rule Clarity and Material Environment. Each item has five frequency response alternatives: Almost Never, Seldom, Sometimes, Often or Very Often (Fraser, Giddings, & McRobbie, 1995; Fraser & McRobbie, 1995). The SLEI was originally field-tested and validated using 5,447 students in 269 classrooms in six different countries: the USA, Canada, England, Israel, Australia and Nigeria. It was then cross-validated in Australia with 1,594 students in 92 classes by Fraser and McRobbie (1995) and 489 senior high school biology students in Australia by Fisher, Henderson and Fraser (1997).

The SLEI was administered in Singapore using a sample of 1,592 final-year secondary-school chemistry students in 56 classes in 28 coeducational government schools. This study made use of a modified version called the Chemistry Laboratory Environment Inventory (CLEI). The CLEI was used in conjunction with the Questionnaire on Chemistry-related Attitudes (QOCRA), which is a modified version of the Test of Science-Related Attitudes (TOSRA), to examine associations between student perceptions of the chemistry laboratory classroom environment and their attitudes towards chemistry. The study validated the instrument for use with chemistry students in Singapore and revealed that laboratory activities that were integrated into theory lessons provided clear rules and consistently resulted in positive attitude outcomes. Also, Open-endedness in laboratory activities was negatively related to attitudes to scientific inquiry in chemistry (Wong & Fraser, 1996).

In a study of differences between gifted and non-gifted secondary-school chemistry students in Singapore, the CLEI was again used. There was a positive association between Open-endedness and Material Environment and attitudes to chemistry among gifted students. The CLEI was found to be valid and reliable with this sample of 497 students (Quek et al., 2005).

The SLEI was used in a study of 761 high-school biology students in Miami to evaluate the use of anthropometric activities in terms of classroom environment. Analysis of questionnaire responses supported the SLEI's factorial validity and internal consistency reliability, as well as its ability of each scale to differentiate between the perceptions of students in different classrooms. Also, the use of anthropometric activities promoted a positive classroom learning environment (Lightburn & Fraser, 2007).

When a Korean-language version of the SLEI was administered to 439 high-school science students, students in the science-independent stream perceived their learning environment more favorably than students in the humanities or science-oriented stream. The study supported the factorial validity and internal consistency reliability of the SLEI as well as the ability of each scale to differentiate between perceptions of students in different classrooms (Fraser & Lee, 2009).

2.2.2.8 Constructivist Learning Environment Survey (CLES)

The Constructivist Learning Environment Survey (CLES) was developed to assess the degree of constructivism in the classroom environment. Because individuals make sense of the world using knowledge that they have already constructed, this survey assesses the prevalence of opportunities for students to construct their own knowledge. The constructivist classroom involves negotiation and consensus building and the CLES assesses these facets of the classroom with 36 items involving five different scales: Personal Relevance, Uncertainty, Critical Voice, Shared Control and Student Negotiation. There are five frequency response alternatives ranging from Almost Never to Almost Always in both the actual and preferred forms (Taylor, Fraser, & Fisher, 1997).

The CLES was administered to 1,081 students in 50 classes in Australia and a Mandarin translation was administered to 1,879 students in 50 classes in Taiwan in a cross-national study of junior high school science classroom learning environments. For versions in both languages, Aldridge, Fraser, Taylor and Chen (2000) reported sound factorial validity reliability and the ability of the instrument to differentiate between classrooms. The researchers reported that classes in Australia were perceived as being more constructivist than the classes in Taiwan, especially in relation to Critical Voice and Student Negotiation (Aldridge et al., 2000).

A diverse sample of 1,079 students in 59 science classes in North Texas was used to support the strong validity of the CLES. The questionnaire is capable of differentiating between the perceptions of students in different classes. This study of a teacher professional development program, called the Integrated Science Learning Environment (ISLE) model, revealed that the students of the teachers in the program viewed their classroom learning environments more favorably than students of teachers not in the program (Nix, Fraser, & Ledbetter, 2005).

The CLES was validated in a study of 1083 students and 24 science teachers in 12 different schools in Korea by Kim, Fisher and Fraser (1999). The main purpose of the study was to investigate whether science curriculum reform in Korea had a positive impact on the constructivist classroom learning environment. In the study, tenth graders had more positive perceptions of their learning environment, which involved a general science curriculum centered around inquiry and negotiation, than did the eleventh-graders who studied an academic-centered science curriculum. When the CLES was administered for the first time in the Korean language and cross-validated with a sample of 1,083 students in 24 tenth-grade science classes, it was found to be valid and reliable. The study also revealed a relationship between classroom environment and student attitudes. Students were found to have attitudes that are more favorable in classes where students perceive more Personal Relevance and Share Control over their learning. Students also seemed to prefer a more positive classroom environment than what they perceived to prevail. The study identified different views and outcomes between tenth and eleventh graders. The implications of the research could be used to further curriculum reform particularly in eleventh grade (Kim et al., 1999).

Aldridge, Fraser and Sebela (2004) used an English version of the CLES in a study in South Africa with 1,864 students in 43 mathematics classes from grades 4 – 6. The study was focused on helping teachers to become reflective practitioners in their daily mathematics teaching. The questionnaire was modified to enhance its suitability in South African mathematics classrooms. The factorial validity, internal consistency reliability and ability to differentiate between classrooms of this modified version was satisfactory for both the individual and class mean levels of analysis and for both the actual and preferred forms. In a second phase of the study, two teachers used the student responses to the CLES to guide the design of teaching strategies for improving their constructivist learning environments. The teachers were successful in improving student scores on the CLES and were able to achieve scores closer to what learners would prefer to happen in their mathematics classroom. The study supported the efficacy of the CLES for providing feedback that was able to guide teachers in changing their classroom practices to a more constructivist classroom. The CLES can therefore be used as a reflective tool in action research for teachers aiming to improve their constructivist learning environments (Aldridge, Fraser et al., 2004).

Peiro and Fraser (2009) administered a modified version of the CLES to 739 grade K – 3 science students in Miami, USA. The questionnaire was administered in both English and as a translated Spanish version. The analysis supported the validity of the instrument in both languages when used with young students. Positive associations were found between students' attitudes and the nature of the classroom learning environment and an intervention over three months led to positive changes in the classroom environment.

2.2.2.9 What Is Happening In this Class? (WIHIC)

The What Is Happening In this Class? (WIHIC) questionnaire was designed to address contemporary concerns in education. The WIHIC consists mainly of scales from a wide range of existing questionnaires. It is the instrument used most often today in classroom learning environment research (Dorman, 2008).

The WIHIC originally contained 90 items that were eventually refined down to 56 items addressing seven scales: Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation and Equity. The WIHIC also has a separate Class Form (which assesses the student's perceptions of the class as a whole) and a Personal Form (which assesses a student's personal perceptions of his or her role in the classroom learning environment) (Aldridge, Fraser, & Huang, 1999). The WIHIC was found to have strong factorial validity and internal consistency reliability, as well as being capable of differentiating between the perceptions of students in different classrooms, in both the English and Chinese languages (Aldridge & Fraser, 2000). An Australian sample of 1,081 students and a Taiwanese sample of 1,879 students was used to both refine the instrument and support its validity (Aldridge & Fraser, 2000; Aldridge et al., 1999).

A Korean version of the WIHIC was developed and validated in a study of 543 students in 12 different Korean schools (Kim et al., 2000). Each scale was found to display satisfactory factorial validity, internal consistency reliability and discriminant validity. The perceptions of students in different classrooms were significantly different as well. The results of the study further supported the assertion that the classroom learning environment has an impact on how well students achieve desired outcomes. The study showed that students perceived their Korean science classrooms as having lower levels of Teacher Support, Involvement and Cooperation relative to other scales. Males also perceived more Teacher Support, Involvement, Investigation, Task Orientation and Equity than female students (Kim et al., 2000).

Studies conducted by Dorman (2003, 2008) involved large numbers of high-school students from Australia, the UK and Canada to validate the WIHIC. Dorman's 2003 study involved 3,980 students whereas Dorman's 2008 study involved 978 students. Use of confirmatory factor analysis in both studies and multitrait-multimethod modelling in the recent study (Dorman, 2008) provided strong evidence that the WIHIC is a valid and reliable tool to assess psychosocial aspects of the learning environment across countries, grade levels and genders.

The WIHIC was used to investigate the use of Internet technologies in a study involving 1,040 high-school students in Australia and Canada. The researchers examined factors influencing student satisfaction with their learning in these 'technological settings'. The study supported the factorial validity and internal consistency reliability of the WIHIC and identified numerous physical barriers, such as equipment placement, as interfering with the effectiveness of the 'technological setting' (Zandvliet & Fraser, 2004).

The WIHIC was used in conjunction with the QTI in a study of 1,021 students in Jammu, India. The study aimed to examine the cultural influences on student perceptions of the classroom learning environment. Koul and Fisher (2005) found that the WIHIC was valid and reliable for use in research on classroom learning environments in India. The study showed that students with cultural backgrounds that valued education as linked to an individual's success in adulthood had more positive views of their teacher's interpersonal relationships and classroom learning environment than those individuals whose cultural expectations were to help to run the family business (Koul & Fisher, 2005).

Further validation of the WIHIC was provided for a sample of 665 middle-school science students from California in a study of the factors that influence students' perceptions of their learning environments. In this study, females generally had more positive perceptions of their learning environment than the males. The study also linked smaller class size to more positive perceptions of the learning environment (den Brok, Fisher, Rickards, & Bull, 2006).

In a unique study, the perceptions of students as well as parents were reported using the WIHIC among 520 students in grades 4 and 5 and 120 parents; the research was conducted in South Florida. The factorial validity, internal consistency reliability and ability to differentiate between perceptions of students from different classrooms were supported by the data analysis. Both students and parents preferred a more positive classroom environment than they perceived as being present; however, parents seemed to have a greater gap between their actual and preferred responses to the WIHIC. In addition, parents and students were satisfied with the classroom learning environment. Parents, however, were less satisfied than students and would prefer more Teacher Support, whereas students preferred more Investigation (Allen & Fraser, 2007). Contrasting results were found in another study involving 172 kindergarten students and 78 parents in Florida, with parents perceiving a more favorable classroom learning environment than students, but preferring a less favorable environment than students (Robinson & Fraser, in press).

A study of 1,434 middle-school physical science students in New York further validated the WIHIC questionnaire in terms of factorial validity and internal consistency reliability. For a subsample of 165 students, inquiry-based laboratory activities promoted more Student Cohesiveness than non-inquiry-based activities. Inquiry was differentially effective for males and females. Males benefited more from inquiry than females, who benefited more from non-inquiry laboratory activities (Wolf & Fraser, 2008).

Two studies in Florida, USA further validated the WIHIC's factorial validity and reliability. Pickett and Fraser (2009) conducted a study using 573 students in grades 3–5. This research monitored changes in the learning environment in beginning teachers' classrooms. When Helding and Fraser (in press) used the WIHIC with 924 students is 38 different science classes in grades 8 and 10, the study contributed a Spanish translation of the instrument, as well as revealing positive associations between the learning environment and attitudes and achievements. In addition, students of National Board Certified (NBC) teachers had more positive perceptions of their classroom learning environment than students of non-NBC teachers.

Computer application courses and adult education were the focus of another study involving and further validating the WIHIC. The study involved 250 working adults attending courses in computer education centers in Singapore. The study supported the factorial validity and internal consistency reliability of the WIHIC, and suggested that students were more satisfied with their computer application courses when there was more Teacher Support, Involvement and Task Orientation (Khoo & Fraser, 2008).

In a study of 2,310 tenth-grade geography and mathematics students in Singapore, the WIHIC was used in investigating relationships between classroom environment with achievement, attitudes and self-esteem. The WIHIC was found to be valid and reliable. The study also revealed that better examination scores were associated with classrooms with more Student Cohesiveness, but that self-esteem and attitudes were more favorable in classrooms with more Teacher Support, Task Orientation and Equity (Chionh & Fraser, 2009).

In research involving 1,077 primary school students in South Africa, the WIHIC was used to identify discrepancies between actual and preferred learning environments. The feedback about actual-preferred discrepancies was used by teachers in formulating teaching strategies. This study involved modifying and validating the WIHIC questionnaire in the IsiZulu language for use in primary schools in South Africa. The study suggested that reflective teaching practice based on feedback from surveys of student perceptions of the learning environment is a meaningful way to enhance teaching styles and practices (Aldridge, Fraser, & Ntuli, 2009).

Sound factorial validity and internal consistency reliability were exhibited by the WIHIC in a study of 763 college students in Dubai. Parallel English and Arabic versions were created to allow students a personal choice in the language of the questionnaire. The study once again revealed that students preferred a more favorable classroom learning environment than what they perceived to be present (MacLeod & Fraser, 2010). In another study of 352 college students in 33 classes, an Arabic translation was also used (Afari, Aldridge, Fraser, & Khine, in press). The study focused on the effect of mathematical games on the classroom environment perceived by students; the use of mathematical games appeared to foster a positive classroom learning environment. Also, learning environment was related positively to Enjoyment and Academic Efficacy. The study was one of the first learning environment studies to be conducted in the United Arab Emirates using the Arabic translation; satisfactory factorial validity and reliability were reported for the Arabic version of the WIHIC (Afari et al., in press).

A cross-validation of the WIHIC in Australia and Indonesia involved a sample of 1,161 students and supported the validity of the instrument. The study also revealed differences between countries and sexes in students' perceptions of the science classroom learning environment. Indonesian students' perceptions of Involvement and Investigation were more positive than the perceptions of the Australian students; however Task Orientation and Equity were viewed more positively by the Australian students (Fraser, Aldridge, & Adolphe, 2010).

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

Whereas Section 2.2.2.9 reviewed literature related to the widely-used WIHIC, this section is devoted to a recent instrument (the TROFLEI), which is based largely on the WIHIC and which was used in the current study. The Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) measures 10 dimensions of classroom environments from two frames of reference: actual (what the student perceives is happening) and preferred (what the student wishes to happen). The actual and preferred are presented to students in a side-by-side format that helps to reduce the size and redundancy of the questionnaire. The TROFLEI uses all seven dimensions from the WIHIC, namely, Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Investigation, Cooperation and Equity, but also adds three important new scales. These three scales are Differentiation, Computer Usage and Young Adult Ethos (Aldridge & Fraser, 2008).

This particular questionnaire can be used in action research to provide teachers with insight into how to create more outcomes-focused learning environments. Feedback from this questionnaire was used by teachers in Australia to improve their classroom environments based on their students' perceptions (Aldridge & Fraser, 2008, 2011).

Both the actual and preferred forms of the TROFLEI were established as reliable and valid using a sample of 2,317 student responses from students in Western Australia and Tasmania. Aldridge, Dorman and Fraser (2004) used multitrait-multimethod modelling in a study involving 1,249 students from Western Australia and Tasmania. In their analysis, they treated the 10 scales of the TROFLEI as traits and the actual and preferred forms as methods. The study revealed that the instrument had strong factorial validity and sound psychometric properties. The results also indicated that the actual and preferred forms of the instrument share a common structure.

The TROFLEI was originally developed to use in monitoring and evaluating a new school with outcomes-focused education. Changes found in students' perceptions of their classroom learning environments over the four years supported the efficacy of the school's outcomes-focused approach. Responses also showed differences in perceptions according to gender and whether students were enrolled in university-entrance examinations and wholly school-assessed subjects (Aldridge & Fraser, 2008, 2011).

Dorman and Fraser (2009) conducted a study of relationships between student affective outcomes and TROFLEI scales, gender, grade level and access to a home computer and the internet. When the TROFLEI was administered to 4,146 high-school students from Western Australia and Tasmania, it was found to be valid and reliable in terms of factorial validity and internal consistency reliability. Although the analysis did not reveal any significant effects on student outcomes due to gender, grade level or technology access, improvement of the classroom learning environment had the potential to improve student outcomes.

Recently Koul, Fisher and Shaw (2011) conducted a study using 1,027 high-school students from 30 classes in New Zealand. Both the actual and preferred forms of the TROFLEI were administered to investigate differences between students' perceptions of their actual and preferred learning environments, as well as year-level and gender differences in learning environment perceptions. The study also investigated associations between science classroom learning environment and attitudes and self efficacy. The study established the validity and reliability of the TROFLEI in New Zealand, and differences between actual and preferred responses indicated that students in the study sought better learning environments. Females and older students generally perceived their technology-rich learning environments more positively (Koul et al., 2011).

2.3 Student Attitudes Towards Science: Background and Assessment

Because this study involved the assessment of attitudes, Section 2.3 reviews literature related to the historical progression of the field of research on, and factors related to, students' attitudes towards science.

2.3.1 Background to Science Attitudes Research

According to Fraser (1998b, 2007) and Walker (2006), the learning environment created by teachers is likely to influence students' attitudes. However, according to Mueller (1986), attitudes cannot be measured or observed directly and so their existence should be inferred from their consequences. According to Kind, Jones and Barmby (2007), attitudes are feelings that a person has about an object based on beliefs that he or she holds about that object. Reid's (2006) definition of attitudes involves three components: cognitive (knowledge of the object, belief or idea), affective (feelings regarding the object) and behavioral (the tendency towards action).

Past research has shown the importance of positive attitudes in science for encouraging individuals to choose post-secondary career paths in science (Hofstein & Walberg 1995; Ormerod & Duckworth, 1975; Osborne & Simon, 1996). An inquiry into the choice of science and technology in higher education led to the identification of 'the swing from science' (Ormerod & Duckworth, 1975). Some explanations of 'the swing from science' included: lessening interest in science and a disaffection with science and technology amongst students (Ormerod & Duckworth, 1975). The number of students pursuing science in higher education was on the decline, and Osborne and Simon (1996) attributed this to disinterest among females and the low quality of teaching.

Research into science attitudes began with Perrodin (1966), who examined elementary-school science students' attitudes towards science education. Perrodin compiled over 500 open-ended statements from US students in grades 4, 6 and 8. This was a comprehensive undertaking involving gathering, transcribing and organizing student responses in order to make final qualitative judgments regarding attitudes towards science (Perrodin, 1966).

The Scientific Attitude Inventory (SAI) was developed by Moore and Sutman (1970) as a test for intellectual and emotional attitudes towards science for secondary-school students. The instrument contained 60 items assessing constructs ranging from knowledge of scientific laws and theories to feelings about being a scientist (Moore & Sutman, 1970). For many years, the SAI was the primary instrument used for research on science attitudes. The instrument was so prevalent that Munby (1983) reviewed 30 studies using the SAI and questioned its validity. Twenty-five years later, Moore and Foy revised the SAI based on suggestions made by researchers who had used the instrument. The SAI II was designed to improve readability and eliminated gender-biased language. The response format was changed to a five-point Likert scale as the questionnaire's length was reduced to just 40 items (as compared to the original SAI with 60 items). Responses from 557 students in grades 6, 9 and 12 were used to validate the SAI II (Moore & Foy, 1997).

Another widely-used instrument over several decades is the Test of Science Related Attitudes (TOSRA) (Fraser, 1981). Because a scale from TOSRA was selected and modified for use in this study, literature related to TOSRA is reviewed in greater detail in Section 2.3.2.1

According to numerous authors (e.g. (Kind et al., 2007; Munby, 1983, 1997; Osborne, Simon, & Collins, 2003), many existing instruments for assessing attitudes toward science are plagued by numerous important, long-standing and well-known problems. These include a lack of clarity in the descriptions of the constructs being measured, the combining of separate and conceptually-distinct constructs into one scale, low reliability, and failure to demonstrate construct validity. Fortunately, for the Attitude and Efficacy Questionnaire used in the current study (see Section 2.3.2), each of these problems is overcome.

In classrooms with higher levels of involvement, teacher support and use of innovative teaching strategies, students reported more positive attitudes towards science (Myers & Fouts, 1992). Osborne and Simon (1996) further supported associations between learning environments and attitudes. Lack of ability, confidence and enthusiasm for science by teachers was found to lead to less stimulation, and therefore, to students with poor attitudes towards science (Osborne & Simon, 1996). Jarvis and Pell (2005) also concluded that the teacher's style and instructional decisions influence students' attitudes towards science.

2.3.2 Attitude and Efficacy Questionnaire

Because attitude outcomes are often overlooked when researching outcomes related to classroom learning environment, Aldridge and Fraser (2008) developed the Attitude and Efficacy Questionnaire. The three scales in this questionnaire are Attitude to Subject, Attitude to Computer Use and Academic Efficacy; the third scale was adapted from the Morgan-Jinks Student Efficacy Scale (MJSES) (Jinks & Morgan, 1999). Because each of these three scales was included in the current study, they are discussed in turn in Sections 2.3.2.1 to 2.3.2.3 below. The Attitude and Efficacy Questionnaire can be found in Appendix A as the final part of the survey distributed to students during the main study.

2.3.2.1 Attitude to Subject

Fraser (1978) published an article describing the Test of Science-Related Attitudes (TOSRA) and received many requests for copies of the instrument. A handbook describes the instrument, its administration, and the statistical analysis of responses (Fraser, 1981). When Munby (1983) reviewed 56 science attitude instruments, he concluded that TOSRA is "an exceptionally well developed scale" (p. 314).

The seven scales of the TOSRA were designed to coincide with the six categories in Klopfer's taxonomy that clarifies the meaning of the term 'attitude to science': attitudes to science and scientists, attitude to inquiry, adoption of scientific attitudes, enjoyment of science learning experiences and interest in a career in science. The seven scales of the TOSRA are: Social Implications of Science, Normality of Scientists, Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science and Career Interest in Science. Students respond to the 70 statements (10 in each scale) using a Likert scale ranging from Strongly Agree to Strongly Disagree. The TOSRA allows the generation of a profile of attitude scores for individual students and for the class as a whole (Fraser, 1981).

The TOSRA has been used to assess students' attitudes in both its original and modified forms (Quek et al., 2005; Spinner & Fraser, 2005). Martin-Dunlop and Fraser (2007) used a sample of 525 female students in a large urban university in the

USA to investigate the effects of an innovate science course for improving prospective elementary teachers' attitudes towards science. Although the prospective elementary teachers only 'sometimes' looked forward to lessons, they felt that lessons were fun and not boring and indicated that lessons made them interested in science; positive associations between learning environment and attitudes were found. Associations between a favorable learning environment and positive student attitudes were strongest for instructor support (Martin-Dunlop & Fraser, 2007).

The TOSRA has been found to be valid and reliable in multiple studies that also reported positive associations between classroom learning environment and attitudes. Butts and Fraser (1982) conducted a study involving 712 junior high-school science students in Australia which further validated the TOSRA and found positive associations between individualization in the learning environment and attitudes.

Wong and Fraser (1996) conducted a study involving 1,592 tenth-grade chemistry students in Singapore. Again, the TOSRA was found to be valid and reliable, and positive associations between the learning environment and attitudes were reported.

Fraser, Aldridge and Adolphe (2010) conducted research involving 567 students in Australia and 594 students in Indonesia in 18 secondary science classes. The study supported the factorial validity and reliability of the TOSRA. Their research also yielded differences between the countries and genders, as well as associations between the learning environment and attitudes.

The Attitude to Subject items in the Attitude and Efficacy Questionnaire used in this study were adapted by Aldridge and Fraser (2008) from the TOSRA's Enjoyment of Science Lessons Scale (Fraser, 1981). The scale contains eight items (items 1 – 8) and can be found in Appendix A.

2.3.2.2 Attitude to Computer Use

The Attitude to Computer Use items in the Attitude and Efficacy Questionnaire used in this study were adapted from the Computer Attitudes Survey (CAS) (Loyd & Gressard, 1984; Newhouse, 2001).

Newhouse (2001) modified the original version of the CAS consisting of 30 mixed positively- and negatively-worded items. The current version containing eight positively-worded items were taken from Newhouse's new version and assess students' enjoyment or anxiety associated with computer usage. The Attitude to Computer Use Scale contains eight items (items 9 – 16) and can be found in Appendix A.

Mitra and Steffensmeier (2000) and Teo (2006) reported that accessibility to computers fosters positive attitudes toward computer use. Students with positive attitudes towards computer use were more likely to have positive attitudes towards computers in their learning (Liu, Macmillan, & Timmons, 1998).

2.3.2.3 Academic Efficacy

Academic efficacy is an individual's belief that he or she can achieve at a certain defined level on a task or attain a specific goal (Bandura, 1997; Eccles & Wigfield, 2002). According to Eccles and Wigfield (2002), academic expectancy can be categorized into two distinct expectations: academic outcomes and academic efficacy. Academic outcomes expectations are a student's beliefs that specific behaviors will lead to specific outcomes. For example, students might believe that doing their homework will lead to a higher grade in a course. Academic efficacy expectations are students' beliefs in their ability to perform necessary behaviors to produce specific outcomes. For example, a student might believe that studying for an examination will lead to a higher grade. Academic efficacy expectations are students' beliefs that they have the ability to accomplish a goal because they are confident in their ability in the subject (Eccles & Wigfield, 2002).

Eccles (2005) found that self efficacy associated with academic achievement accounted for 25% of achievement variance above the effects of instructional practice. According to Lorsbach and Jinks (1999), students' efficacy beliefs in their competence could lead to improved learning environments and therefore more positive student outcomes.

Higher self efficacy directly impacts academic achievement by increasing the quality and quantity of information processing. Students with high self efficacy have been found to be more likely to use a wide range of strategies, be more flexible in investigation and process information at deeper levels (Pajares, 1996; Schunk, 1989).

The Academic Efficacy items contained in the Attitude and Efficacy Questionnaire used in this study were adapted from the Morgan-Jinks Student Efficacy Scale (MJSES) (Jinks & Morgan, 1999). The Academic Efficacy Scale contains eight items (items 17 – 24) and can be found in Appendix A.

2.4 Past Research Involving Learning Environment Questionnaires

There have been many different foci in past learning environments research according to literature reviews (Fraser, 1998b, in press). The subsections below provide reviews of research involving: teachers' attempts to improve classroom and school environments (Section 2.4.1); differences between students' and teachers' perceptions of actual and preferred environment (Section 2.4.2); person-environment fit studies of whether students achieve better in their preferred environment (Section 2.4.3); the joint influence of two or more educational environments (Section 2.4.4); evaluation of educational innovations (Section 2.4.5); and associations between learning environments and student outcomes (Section 2.4.6).

2.4.1 Teachers' Attempts to Improve Classroom and School Environments

According to Fraser (1981, 1986), feedback information based on student and/or teacher perceptions can be used for reflection, discussion of and attempts to improve learning environments. Fraser and Fisher (1986) further delineated an action research protocol involving a five-step process involving assessment, feedback, reflection and discussion, intervention and reassessment.

Aldridge, Fraser and Sebela (2004) administered an English version of the CLES to 1,864 South African mathematics students in 43 classes in grades 4 – 6. The study focused on helping South African teachers to become more reflective practitioners in their daily teaching. The CLES was used in teacher action research and improvements in the constructivist nature of the classrooms were achieved through the implementation of a 12-week intervention. This study led to the cross-validation of the English version of the CLES in terms of factorial validity, internal consistency reliability and ability to differentiate between classrooms (Aldridge, Fraser et al., 2004).

Sinclair and Fraser (2002) developed a middle-school questionnaire based on the MCI and WIHIC for teachers who are interested in conducting action research. The instrument was validated using a sample of 745 students in 43 grade 6–8 classes. Four scales of Cooperation, Teacher Empathy/Equity, Task Orientation and Involvement are contained in the instrument designed to evaluate classroom learning environments; the instrument is called the Elementary and Middle School Inventory of Classroom Environments (ICE). Three teachers in the study also used the ICE in action research. In all three case studies, positive changes were observed for those ICE dimensions that each teacher chose to improve (Sinclair & Fraser, 2002).

Yarrow, Millater and Fraser (1997) conducted a study aimed at improving the environment of university teacher education classes and primary school classroom environments during practice teaching for 117 preservice teachers. The study involved action research in which assessments of student perceptions of both the actual and preferred learning environments were measured using the College and University Classroom Environment Inventory (CUCEI) for the preservice teachers and the My Class Inventory (MCI) to survey their primary school students. Preservice teachers valued the inclusion of the topic of learning environments and the action research included in their teacher education program. The study revealed many cases for which the use of classroom environment assessments aided the improvement of classrooms.

Aldridge, Fraser, Bell and Dorman (in press) constructed the Constructivist-Orientated Learning Environment Survey (COLES) to incorporate scales from the WIHIC (Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Cooperation and Equity), the TROFLEI (Differentiation and Young Adult Ethos) and the CLES (Personal Relevance) in an instrument that is designed for feedback in teacher action research. Also, Aldridge et al. created the two new scales of Formative Assessment and Assessment Criteria. The Formative Assessment scale was designed to measure the extent to which assigned assessment tasks make a positive contribution to student learning. The Assessment Criteria scale was designed to measure the explicitness of assessment criteria. When Aldridge et al. (in press) used the COLES with a sample of 2,043 grade 11 and 12 students in 147 classes in nine schools in Western Australia, the sound factorial validity and internal consistency reliability of both actual and preferred versions were supported. The study also found that the COLES was capable of differentiating between the perceptions of students from different classrooms.

Aldridge et al. (in press) reported that the COLES was a viable instrument when used to provide feedback to teachers conducting action research focused on improvement of classroom learning environments. Aldridge et al. studied teachers' use of feedback on students' actual and preferred learning environment perceptions while conducting research aimed at improving learning environments. Both the actual and preferred forms of the COLES were administered prior to (pretest) and after (posttest) implementation of teaching strategies aimed at reducing the discrepancy between actual and preferred responses on selected COLES scales. After evaluating reflective journals, written feedback, forum discussions and teacher interviews, Aldridge et al. (in press) noted that teachers felt that the feedback information provided by the COLES was valuable for guiding decisions about implementing classroom changes that resulted in improvements to the learning environment.

2.4.2 Differences Between Students' and Teachers' Perceptions of Actual and Preferred Environment

Fisher and Fraser (1983a) used the ICEQ with 116 classes taught by 56 teachers. The actual and preferred forms of the ICEQ were used to compare student and teacher responses. Both students and teachers generally preferred a more positive learning environment than they perceived, and teachers perceived a more positive learning environment than the students perceived.

Allen and Fraser (2007) used English and Spanish versions of the WIHIC with 120 parents and 520 grade 4 and 5 students in Florida, USA. This particular study revealed positive associations between learning environments and attitudes as well as achievement. This study involved the investigation of differences in scores on the actual and preferred forms of the WIHIC by both students and their parents. This research revealed larger differences between actual and preferred scores for parents than for students.

2.4.3 Person-Environment Fit Studies of Whether Students Achieve Better in Their Preferred Environment

By using both actual and preferred forms of classroom learning environment instruments, researchers can examine if there is a relationship between the congruence in actual and preferred learning environments and student outcomes. In a study involving the match between students' preferred learning environment and actual environment, Fraser and Fisher (1983b, 1983c) used the CES and ICEQ to reveal that 'person-environment fit' was as important as the learning environment itself. Person-environment fit was defined as the degree of congruence between students' preferences and the actual environment (Fraser & Fisher, 1983b, 1983c). The outcomes of the study suggest that attempting to change actual learning environments to those preferred by the class could lead to higher student achievement and attitude scores.

According to Hunt (1975), behavior is a function of the person and the environment. According to Mitchell (1969), educational psychologists should look into how to predict behavior based on the person-environment interaction. In this new model, educators should focus on coordinating individual differences and the effects of the environment (Hunt, 1975).

2.4.4 Joint Influence of Two or More Educational Environments

There have been several studies designed to explore the possibility of joint influences by two or more educational environments. Marjoribanks (1991) identified the home and school environments as codeterminents of student achievement. Home, school and parents' work environments have been found to have a joint influence on student achievement (Moos, 1991).

Fraser and Kahle (2007) used secondary analysis from a Statewide Systemic Initiative (SSI) in the USA to examine the effects of several different types of environments on student outcomes. The data collection involved nearly 7,000 students from 392 middle-school science and mathematics classes in 200 schools over three years. A questionnaire was designed to assess class, home and peer environments, along with student attitudes and achievement. In this study, all three environments were independently related to student attitudes, whereas only the classroom learning environment showed a significant independent association with student achievement (Fraser & Kahle, 2007).

2.4.5 Evaluation of Educational Innovations

Learning environment instruments have proved to be useful as a source of criteria for the evaluation of educational innovations. Because the current study involved an evaluation of an educational innovation, namely, Classroom Performance System (CPS) technology integration, a review of existing literature on the topic is provided below.

Evaluating educational innovations have been one of the foci of learning environment research for over four decades. During the late 1960s, the LEI was developed for an evaluation of Harvard Project Physics. The LEI was one of the first instruments to be used in the evaluation of a new curriculum (Fraser et al., 1982; Walberg & Anderson, 1968).

Nix, Fraser and Ledbetter (2005) used the CLES to evaluate a science teacher development program. The effects of a science teacher development program on classroom learning environment were examined using 445 students in 25 classes. Students responding to the CLES compared their class to other classes at the same school taught by different teachers. Students of teachers who had received the professional development perceived higher Personal Relevance and Uncertainty than students of teachers who did not receive the professional development (Nix et al., 2005).

Khoo and Fraser (2008) used learning environment instruments in evaluating computer application courses for adults. The WIHIC was adapted for a sample of 250 working adults attending five computer education centers in Singapore. The WIHIC was found to be valid and reliable when used with a group of working adults in Singapore. Students generally perceived a positive classroom learning environment. However, males perceived more Involvement whereas females perceived more Equity. Relative to younger females, older females had more positive perceptions of Trainer Support (Khoo & Fraser, 2008).

Wolf and Fraser (2008) used responses to the WIHIC from 1,434 middle-school physical science students in New York to further validate the WIHIC questionnaire. Using a subsample of 165 students, Wolf and Fraser found that inquiry instruction promoted more Student Cohesiveness than non-inquiry instruction. Males benefited more from inquiry than females, who benefited more from non-inquiry laboratory activities (Wolf & Fraser, 2008).

In a study of 761 high-school biology students in Miami, Lightburn and Fraser (2007) used the SLEI to evaluate the use of anthropometric activities in terms of classroom environment. Generally, the use of anthropometric activities promoted a positive classroom learning environment (Lightburn & Fraser, 2007).

The TROFLEI was used in monitoring and evaluating a new senior high school in Australia that promoted outcomes-focused educational programs. When a total of 1,918 students were surveyed over a four-year period, changes in student perceptions of the classroom learning environment from year to year supported the efficacy of the programs. Also, gender and whether a subject was for university entrance or wholly school-assessed affected the degree of change over time in perceptions of the learning environment (Aldridge & Fraser, 2008, 2011).

Pickett and Fraser (2009) involved 573 students in upper-elementary grades in monitoring changes in the learning environment in beginning teachers' classrooms during a two-year mentoring program. A modified version of the WIHIC was used to assess students' perceptions of the learning environment as both a pretest and posttest. The study supported the efficacy of the mentoring program in terms of some improvements over time in the learning environment, as well as in students' attitudes and achievements (Pickett & Fraser, 2009).

Afari and colleagues (in press) used the WIHIC to survey 352 college students in 33 classes from the United Arab Emirates who used mathematical games in an attempt to promote a positive classroom learning environment. When the WIHIC was translated into Arabic in this study, it was found to have sound factorial validity and internal consistency reliability for this population of college students. Analysis of data revealed that mathematical games appeared to foster a positive classroom learning environment and led to more positive attitudes in the areas of Enjoyment and Academic Efficacy (Afari et al., in press).

2.4.6 Associations Between Learning Environments and Student Outcomes

In the field of learning environments research, much attention has been paid to associations between learning environments and student outcomes. The following is a review of studies of the associations between learning environments and student outcomes, as it is relevant to one of the research questions in the current study.

Numerous studies have shown that students' perceptions of the learning environment account for variance in a variety of learning outcomes (Fraser, in press). Fraser (1994) tabulated 40 past studies in science education in order to illustrate the associations found between outcomes and classroom learning environment perceptions through the use of a wide array of instruments, grade levels and countries.

Some examples of studies of associations between learning environments and student outcomes include:

- The SLEI was used in studies of associations with students' cognitive and affective outcomes involving 489 senior-high school biology students in Australia (Fisher et al., 1997), approximately 80 senior-high school chemistry classes in Australia (Fraser & McRobbie, 1995; McRobbie & Fraser, 1993) and 1,592 tenth-grade chemistry students in Singapore (Wong & Fraser, 1996).
- The QTI was used in research that linked student outcomes with perceptions of teacher-student interaction involving 489 senior-high school biology students in Australia (Fisher, Henderson, & Fraser, 1995) and 1,512 primary school mathematics students in Singapore (Goh, Young, & Fraser, 1995).
- The WIHIC was used to link learning environments with student outcomes in a multitude of studies, including research by Aldridge, Fraser and Huang (1999) and Aldridge and Fraser (2000) with junior-high school students from 50 classes in Australia (1,081 students) and Taiwan (1,879 students) that revealed associations between environment and enjoyment. Zandvliet and Fraser (2004, 2005) used the WIHIC with 1,401 students in 81 networked classes in

Australia and Canada and found associations between environment and satisfaction. Data collected using the WIHIC with 2,310 tenth-grade geography and mathematics students from Singapore by Chionh and Fraser (2009) revealed associations between environment and achievement, attitudes and self-esteem. When Kim, Fisher and Fraser (2000) used the WIHIC with 543 eighth-grade science students in 12 Korean schools and Khoo and Fraser (2008) conducted a study using 250 working adults in computer education courses in Singapore, associations between environment and attitudes were found. Afari et al. (in press) conducted research in the United Arab Emirates with 352 college students in 82 classes and found associations between environment and enjoyment and academic efficacy.

- A number of studies that used the WIHIC reported associations between environment and attitudes and achievement for samples in the USA:
  - Wolf and Fraser (2008) used a sample of 1,434 middle-school science students from 71 classes in New York.
  - Allen and Fraser (2007) used a sample of 120 parents and 520 fourth- and fifth-grade students in Florida, USA.
  - Robinson and Fraser (in press) used a sample of 78 parents and 172 kindergarten science students in Florida, USA.
  - Helding and Fraser (in press) used 924 students in 38 eighth- and tenth-grade science students in Florida, USA.
  - Ogbuehi and Fraser (2007) used 661 middle-school mathematics students in California, USA.
- When Dorman and Fraser (2009) conducted a study among 4,146 high school students from Western Australia and Tasmania using the TROFLEI, results indicated that improving the classroom learning environment has the potential to improve student outcomes.

One way in which to better understand links between learning environments and student outcomes is to perform multilevel analysis, which acknowledges the existence of multiple levels or hierarchies in classroom learning environment data (Bryk & Raudenbush, 1992). Because classroom environment data typically are derived from students in intact classes, they are inherently hierarchical. Ignoring this nested structure can give rise to problems of aggregation bias (within-group homogeneity) and imprecision. Multilevel analyses differ from other types of analysis in that it enables the researcher to examine simultaneously the effects of both the individual and the group. Multilevel analysis allows the researcher to improve estimations and certainties in exploring the variance in student outcomes accounted for by learning environment variables.

Multilevel analyses have been conducted in a few studies of associations between the learning environment and student outcomes as described below. Studies by Wong, Young and Fraser (1997) and Goh, Young and Fraser (1995) used multiple regression analyses at the individual student and class mean levels. Using Hierarchical Linear Modelling (HLM) analyses, environment variables were studied at the individual level and were aggregated at the class level. HLM analysis is a regression model used frequently in research in education to answer contextual questions by nesting data sets within higher levels of analysis. The HLM analyses normally look at random-effects ANOVA and mean group difference statistics. In Wong, Young and Fraser's (1997) study, 1,592 tenth-grade chemistry students in 56 classes in Singapore were used to investigate associations between student attitude measures and a modified version of the SLEI. In Goh, Young and Fraser's (1995) study, 1,512 fifth-grade mathematics students in 39 classes in Singapore were used to investigate associations between student achievement and attitudes and a modified version of the MCI. Most of the results for outcome-environment associations that were statistically significant in the multiple regression analyses were replicated in the HLM analyses, as well as being consistent in direction.

Haertel, Walberg and Haertel (1981) conducted a meta-analysis involving 734 correlations from 12 studies involving 823 classes, 8 subject areas, 17,805 students and 4 nations. Classroom learning environment dimensions were related to cognitive and affective learning outcomes. Classes with greater Cohesiveness, Satisfaction and Goal Direction and less Disorganization and Friction were found to have more positive student outcomes (Haertel et al., 1981).

Fraser, Walberg, Welch and Hattie (1987) used research syntheses and secondary analyses to further support the association between learning environments and student outcomes. In secondary analyses, classroom climate was incorporated as one factor in a multi-factor model of educational productivity. In this analysis, ability, development and motivation were all linked with learning. Also, learning was more strongly linked with the home and classroom environments than with either peer or media environments. The classroom learning environment also showed a significant association with achievement (Fraser et al., 1987).

2.5 Technology in Classrooms: Need for Evaluation

According to Jukes, McCain and Crockett (2010), the current education system in the United States is becoming obsolete. “We envision a shift from textbooks, brick-and-mortar classrooms, lectures, worksheets, standardized tests, bells – in fact, everything we grew up expecting of school – to learning whenever and wherever it can best happen” (p. 16). Teachers have to change the way in which they teach if they are to prepare students for the future. According to Levin and Wadmany (2008), Information and Communication Technology (ICT) challenges educators on technological abilities, knowledge and expertise.

On a CD-ROM produced by the Thornburg Center of Professional Development, Thornburg states that “technology allows learners to move through conceptual space at the speed of thought” (1993). Jukes et al. (2010) believe that it is vital that educators customize learning for the learner and move away from teaching to a group as educators currently do. They further describe contemporary learning as both virtual and physical, as well as being nonlinear. Teachers no longer have to occupy the same physical space as their students; learning can take place anywhere. There are new technologies that track the progress of an individual through established checkpoints, as well as machines that have the capacity to ‘think’ (Jukes et al., 2010).

Technology can affect teaching and learning “by being a source of knowledge, a medium for transmitting content and an interactive resource furthering dialogue and creative exploration” (Levin & Wadmany, 2008, p. 234). With learning focused on multimedia and connectivity, the classroom becomes collaborative and worldwide, with learning based on discovery and problem solving. Evaluation more than ever before can be holistic (Jukes et al., 2010). According to Jukes et al., “we must recognize that the current education system has been set up to prepare students perfectly for a world that no longer exists" (2010, p. 19).

In a meta-analysis conducted by Bayraktar (2002), it was revealed that computers are more effective when used individually as a supplement to traditional instruction rather than as a substitute. The research also revealed that computers are more effective when used in simulation or tutorial modes. Bayraktar's research suggests that technology such as computer-assisted instruction, when used in conjunction with other teaching strategies, could be beneficial to learning in science areas (Bayraktar, 2002).

The perceptions about technology integration in schools were investigated in a study of 15 mathematics and science teachers and 450 secondary students in Canada. The study suggested that teachers' attitudes towards technology uses in schools are usually negative, while students seem to be enthusiastic (Li, 2007).

Although much research supports the use of technology, there are also many studies that have failed to identify positive outcomes from technology integration. In a case study involving interactive physics multimedia, Yeo, Loss, Zadnik, Harrison and Treagust (2004) reported that the technology might not produce desired outcomes. In this study, students used an interactive multimedia program segment in the context of long jumping to learn about projectile motion. The study revealed that students did not learn the physics concepts targeted in the multimedia; the researchers suggested inappropriate cognitive levels and insufficient reflective points as possible reasons for the ineffectiveness of the technology. These researchers suggested that students therefore should be instructed on how to use the tools to compensate for these shortcomings in cognitive levels and reflective points (Yeo et al., 2004).

Harwell, Gunter, Montgomery, Shelton and West (2001) used the Constructivist Learning Environment Survey with a Grade 6 team of teachers in mathematics, science, language arts and social studies and their 65 students. The team received professional development on Internet use and integrated Internet-based activities into daily lesson plans. The study revealed no significant changes in student perceptions of the learning environment over the duration of the academic year (when comparing pretest and posttest survey data). The teachers in the study used this information to construct a new plan of action to align their classrooms with constructivist pedagogy and more effective use of internet technology (Harwell et al., 2001).

According to Cuban (2001), policymakers have placed too much emphasis on technology integration without sufficient research findings to back up their objectives. Cuban conducted a study of Silicon Valley schools, which revealed that less than 10% of teachers used computers in the classroom at least once a week. His study also concluded that there wasn't any evidence that using information technologies increases student achievement. Cuban's stance is that computers were expected to improve education at a much faster rate than studies are indicating, and therefore that administrators should invest much more time and resources in professional development and support for teachers in how to optimize the technologies for improvements in classroom and student achievement (Cuban, 2001).

Research into the effectiveness of technology integration, in terms of the science classroom learning environment and student attitudes, is needed. In order to understand any changes created by, and the advantages and disadvantages of using technology, comprehensive evaluations of the effectiveness of technology in science are needed.

2.5.1 Classroom Performance Systems: Instantaneous Information

The use of Student Response System (SRS), including Classroom Performance System (CPS), has received mixed reviews in past research. In one study, a graduate-level lecture class in special education was used. Lectures were paired during two-week intervals and one of the lectures used a form of SRS technology to embed assessments on the content presented. The researchers reported that there was increased engagement in lectures and higher scores on weekly quizzes during sessions that used the technology (Blood & Neel, 2008). This study was consistent with the findings of three other studies that showed improvement in engagement and achievement (Draper & Brown, 2004; Hake, 1998; Kennedy & Cuts, 2005). According to Blood and Neel (2008), students reported that they liked using the system and that they felt that it aided their learning.

Judson and Sawada (2002) discuss the long history of response system technologies dating back to the 1960s. When the technology was first being developed and introduced to the field of education, there were no signs of positive student outcomes related to the integration of student response systems. The authors contended that it is the changes in pedagogy that are facilitated by the use of SRS technologies that yield positive outcomes (Judson & Sawada, 2002).

Through the use of a response system called ClassTalk in the Department of Physics and Astronomy at the University of Massachusetts at Amherst, Dufrene, Gerace, Leonard, Mestre and Wenk (1996) found that the tool was important in creating an interactive and student-centered classroom while teaching large courses. The authors of this action research used the technology with approximately 100 students and reported that the response system was engaging students in active learning and enhancing the overall communication in physics lecture classrooms. It is also important to note that this improvement in both engagement and achievement was relatively simple to implement; there was no major change in pedagogy to accomplish these positive changes (Dufresne et al., 1996).

Although many educational technologies have been introduced to facilitate learning in the classroom, technologies like CPS have not been universally adopted. The technology affords the opportunity for students to answer anonymously and gain feedback immediately. Teachers might also use the feedback to make informed teaching decisions. During the past four decades, CPS-like technologies have become cheaper, more sophisticated, more aggressively marketed, more available and more researched. Nevertheless, these technologies have not been widely adopted by educators. It is possible that more research into the effectiveness of the CPS technology would make school districts ‘sign on the dotted line’ and invest in the technology (Freeman, Bell, Comerton-Forde, Pickering, & Blayney, 2007).

In a recent study conducted with just two sections (each about 200 students) of college physics classes for just one week, Nobel Prize-winning physicist Carl Wieman noted that teaching method matters more than the teacher does. In nearly identical classes, one lecture style taught by a highly-rated veteran professor and the other taught by inexperienced graduate students acting as teaching assistants with CPS-like technology, suggests that college students learned more from the teaching assistants than from the veteran (Borenstein, 2011).

As with any technology in the classroom, there are degrees of use for CPS technology. In a study of 498 elementary and secondary educators, use of response systems in instruction was examined (Penuel et al., 2007). The data from the survey yielded four profiles of teacher use based on frequency of use and breadth of instructional strategies employed:

1. *Infrequent User*: Teachers rarely use CPS. When they do, they tend not to use the full range of capabilities or a variety of pedagogical strategies. Teacher rarely uses data to adjust instruction.

2. *Teaching Self-Evaluator*: Teachers use CPS often. Use is primarily to gain feedback on effectiveness of teaching. Uses CPS for summative assessment mostly and rarely involves students in peer discussion. Teacher only uses CPS to prompt whole-class assumptions sometimes. Occasionally uses data to adjust instruction.

3. *Broad but Infrequent User*: Teachers use CPS less frequently than the self-evaluators, but used the system for a wider range of purposes. The teacher uses system to adjust instruction and summative assessment to make judgements about student learning. Sometimes teacher involves the students in peer discussion or uses the CPS to prompt whole-class discussions. Teacher occasionally uses the system to adjust instruction.

4. *Broad and Frequent User*: Teachers use CPS frequently and for a wide range of purposes. Teacher uses CPS for both summative and formative purposes. Teachers sometimes or often involve students in peer discussion or use the CPS to prompt whole-class discussions. Teachers occasionally uses the system to adjust instruction (Penuel et al., 2007).

Penuel et al. (2007) found that teachers who used CPS most frequently and who used the greatest variety of strategies with the technology were more likely to have received professional development and more likely to perceive the technology as more effective with their students. The experimental group teachers in this study fit best into the Teaching Self-Evaluator profile. This study suggests that, if CPS technology is truly an effective instructional tool, then ample professional development should be provided for teachers to use this technology.

A common thread in all of the studies that did not reveal positive findings for the use of SRS technology integration and student outcomes is that the technology was only successful when paired with improvements to pedagogy (Draper & Brown, 2004). In his earlier work, Draper (1998) described what he called ‘niche-specific’ applications of technology. In this application of the technology, educators first diagnose a problem and then develop a technological solution. Therefore, to apply technology to education successfully, educators must put pedagogy first and technology second (Draper, 1998). Crouch and Mazur (2001) concur that voting systems (SRS technology), when used with a particular pedagogical method called ‘peer instruction’, produced improvements in standardized test results.

Palak and Walls (2009) surveyed 113 teachers using a sequential mixed-method design to examine the relationship between beliefs and instructional technology practices among teachers who use technology in technology-rich schools. Evidence showed teachers used technology for administrative purposes most frequently. The study also indicated that teacher used technology to support current teacher-centered practices as opposed to letting the technology support student-centered instruction (Palak & Walls, 2009). It is because of research such as that conducted by Palak and Walls study that Jones (2007) contests that all professional development for technology integration needs to be approached from an instructional viewpoint as opposed to a technical one. Teachers need to learn how to use the technologies to improve their teaching, not just use the technology (Jones, 2007).

In 2004, Hall and others conducted an evaluation of CPS-like technologies in a General Chemistry course at the University of Missouri, Rolla. Evidence from the study indicated that CPS-like technology helped to increase attendance rates, bring problem areas in instruction to the surface, and increase student satisfaction. Most students agreed that class lectures were more engaging and enhanced their learning. Grades were also substantially better during semesters when CPS-like technology was used (Hall, Collier, Thomas, & Hilgers, 2005, August). In a study conducted using survey and performance data from 2,500 students in course Sections using CPS-like technology and 2,500 students in course Sections using a traditional lecture format, researchers found that mean pass rates were significantly higher in the sections for which the technology was integrated (Poulis, Massen, Robens, & Gilbert, 1997).

In a study involving more than 5,000 students taking either traditional lecture courses in physics or courses that used a response system, achievement was significantly higher and the variance in scores was lower for those students in the courses using response systems (Edens, 2009; Poulis et al., 1997). An evaluation of Classroom

Performance System (CPS) technology integration in terms of classroom environment and attitudes was the focus of the current study.

2.5.2 Differential Effectiveness of Technology: Gender Differences

According to King, Gurian and Stevens (2010), looking through the ‘gender lens’ means realizing how gender-related issues affect test scores, grades, discipline referrals, homework completion rates, special education placements and student motivation. Over 20 years, King, Gurian and Stevens have aimed at closing gender gaps in over 2,000 schools across the USA and have summarized the difficulties for both genders. Areas of difficulty for females include lower learning and engagement in science and technology, relational aggression in school and cyberspace and issues with self-esteem. Areas of difficulty for males include lagging learning skills, such as listening and note taking, more struggles with homework, lower grades in most classes (excluding mathematics and some sciences), less motivation and more negative perceptions of the relevance of the curriculum (King et al., 2010). It has been clear for decades that gender differences are relevant when determining teaching strategies and structuring the classroom learning environment.

Society as a whole is concerned with and aware of gender gaps in performance and equality. Girls tend to outperform boys in reading while boys tend to do the same in mathematics (Eliot, 2010). Biologists suggest that gender gaps are epigenetic; environmental factors and social-cultural contexts shape gender gaps. Mental ability is not ‘hardwired’ into the brain; factors such as opportunities, relationships, sense of identity, diet, chemical exposure and parenting styles are known to genetically alter people’s brains and behavioral functions for the duration of their lives (Eliot, 2010). Eliot contests that educators have to abandon the notion of different brains for male and female in order to close the gap between genders. “The range of performance within each gender is wider than the difference between the average boy and girl” (Eliot, 2010, p. 36). According to Eliot, educators need to focus on the idea of differentiating instruction based on learning styles and ignore typical gender stereotypes.

Close attention has been paid to the gender gap in usage of information and communication technology (ICT). Research suggests that the gap in use of ICT has diminished. However, the use of technology in education still seems to affect males and females differently. Gender scripts are embedded in technology designed as educational tools (usually accidentally); these scripts target one gender more than the other. The three major aspects in which these scripts are found are the content, the visual and audio interface, and the instructional structure of the technological tool. Ideally the content and interface should be designed to be equally attractive to males and females (Heemskerk, ten Dam, Volman, & Admiraal, 2009).

The unfortunate reality is that educational technologies do not all exhibit gender inclusiveness; not all technology is equally attractive to both males and females. Greater inclusiveness appears to improve participation and enhance positive attitudes toward learning and technology. Both males and females reported that inclusive technology improved learning, especially for females (Heemskerk et al., 2009).

Christensen, Knezek and Overall (2005) used the Young Children's Computer Inventory and the Computer Attitude Questionnaire with 10,000 Texas public school students from grades 3–12 over years 2000, 2001, 2002 and 2005. The study aimed at replicating the findings from research undertaken for the US Department of Education Technology Innovation Challenge Grant. Researchers found that fifth grade girls enjoyed computers more. Data from 2005 confirmed that, by eighth grade, boys enjoyed computers more. Around age 12, the enjoyment shifts from more positive among females to more positive among males (Christensen et al., 2005).

Both males and females seem to benefit from gender-inclusive technologies. For females, the difference is much more prominent. It has been reported that females' learning improves when the technology being used addresses their interests (Heemskerk et al., 2009). In a study conducted in Alabama among 59 sixth-grade students responding to The Computer Survey (TCS), there were gender differences in students' attitudes towards technology. Most females did not perceive computers as being more difficult for either gender, but several males indicated that they were better at using computers than females (Bain & Rice, 2007). In a study conducted with 600 secondary-school graduate students from Lagos State, Nigeria, female students were found to develop more interest than their male counterparts when the computers were located in computer laboratories connected to the internet (Adebowale, Adewale, & Oyeniran, 2010).

Cady and Terrell (2007) investigated the effect of embedding technology into a fifth-grade science classroom and measured its effect on the self efficacy beliefs of girls in the class. Their research suggests that careful selection and use of computing technology leads females to higher levels of perceived importance and self efficacy toward technology (Cady & Terrell, 2007).

Achievement gaps were examined between males and female in a study among graduating students that traced back from grade-eight through graduation (Bacharach, Baumeister, & Furr, 2003). Gaps in achievement were shown to increase between males and females; the average yearly increase in academic achievement was significantly greater among male than females. Alexakos and Antoine (2003) reported that, by tenth grade, female attitudes towards science become increasingly negative. Less positive attitudes among females can lead to self-imposed limits on career choices in the field of science (Lindstrom & Tracy, 2003).

Because the success of technology can be different for different students, it is important to understand differential effectiveness of technology usage for males and females in science education classrooms. Wolf and Fraser (2008) conducted a study involving 165 students in 8 classes in a school district in New York State to examine the effectiveness of inquiry instruction methods as compared to non-inquiry science activities. The study used the WIHIC and TOSRA as dependent variables. A two-way MANOVA for instructional method and gender revealed differences in the effectiveness of inquiry methods for males and females. Females from the inquiry group had less positive perceptions of Teacher Support, Investigation and attitudes, but more positive perceptions of Cooperation and Student Cohesiveness. In the non-inquiry group, females perceived higher Equity and reported more positive attitudes. Therefore, females perceived non-inquiry instruction more positively and males perceived inquiry instruction more positively. The conclusion was that inquiry pedagogy was differentially effective for males and females (Wolf & Fraser, 2008).

According to Lee (2003), males seem to benefit from the thought processes of females, while females seem to benefit from the confidence of males. If the success of technology is dependent on pedagogy, then it is possible that technology could be differentially effective for males and females. Understanding the differential effectiveness of CPS technology could guide improvements in the pedagogy selected when using CPS technologies. Therefore, differential effectiveness was investigated for males and females for the two instructional methods (CPS and non-CPS) in terms of the nature of the classroom environment and student attitudes toward science.

2.6 Summary

The literature reviewed in this chapter supports the focus of the current study which was framed within the field of learning environments, which has grown greatly over the past several decades. A myriad of past studies that suggest that positive learning environments are consistently related to higher academic achievement and more positive attitudes towards science.

Many instruments have been developed, modified and used in an attempt to quantitatively assess learning environments at all grade levels and subject areas. The instruments reviewed in Chapter 2 were all found to be valid and reliable with large samples of students in past research.

The Technology-Rich Outcomes-Focused Learning Environments Inventory (TROFLEI) was selected for the current study because of its validity and reliability in past research, and because of its relevance to learning environments involving the use of technology. Literature about the TROFLEI was also reviewed in this chapter.

Student attitudes and self efficacy were assessed in the current study using the Attitudes and Efficacy Questionnaire because of its relevance and successful use in past studies. This questionnaire includes three scales: Attitude to Subject, Attitude to Computer Use and Academic Efficacy. The development and use of this questionnaire were reviewed in this chapter.

Literature on technology integration was also reviewed in this chapter. Before widespread implementation of technology integration, research evidence to support its use is needed to guide educators' adoption decisions about using technology to enhance their existing pedagogies and to aid the transformation of their current pedagogies. Data in this area is essential to teachers, administrators and policymakers who need to ensure that devoting resources to technology implementation is warranted.

Literature about gender issues as related to technology and the field of science were also reviewed. In order to understand the differential effectiveness of technology for males and females and to reduce gender gaps in student perceptions and attitudes, teachers need to focus on teaching pedagogies and technologies that meet the learning styles of all students regardless of gender. In the current study, an investigation of whether two methods of instruction (namely, CPS and non-CPS) were differentially effective for males and females in terms of learning environment perceptions and student attitudes was conducted.

Outlined in the following chapter are the methods of the current study which included an examination of the effectiveness of Classroom Performance Systems (CPS) in terms of student attitudes, achievement, and perceptions of the learning environment, with an additional look at the differential effectiveness of CPS technology integration for students of different genders.

Chapter 3
Research Methods

3.1 Introduction

The main purpose of this study was to examine the effectiveness of Classroom Performance Systems (CPS) in terms of student attitudes and perceptions of the learning environment. The current study also examined whether a modified version of the Technology-Rich Outcomes-Focused Learning Environments Inventory (TROFLEI) is valid and reliable when used with a sample from a large school district in New York State. Also, this study investigated the differential effectiveness of CPS technology integration for males and females, as well as associations between learning environments and student attitudes. To investigate these questions, quantitative data were collected through the use of a modified version of the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) and the Attitude and Efficacy Questionnaire.

This chapter describes the research methods used in the present study in terms of: the research questions guiding the study (Section 3.2); the design of the study (Section 3.3); the instruments used to collect the data (Section 3.4); the phases of the study and data collection for each phase (Section 3.5); the sample selected (Section 3.6); administration of the surveys (Section 3.7); data collection (Section 3.8); and data analysis (Section 3.9).

3.2 Research Questions

To examine whether the instruments used in the study were valid and reliable, the first research question was:

Research Question 1:

> *Are the following questionnaires valid when used with a sample for a large school district in New York State:*

(a) *A modified version of* Technology-Rich Outcomes-Focused Learning Environments Inventory (TROFLEI)*?*

(b) Attitude and Efficacy Questionnaire*?*

To examine whether a relationship exists between students' perceptions of the classroom learning environment and student attitudes, the second research question was:

Research Question 2:

> *Are there associations between classroom learning environment and student attitudes toward science?*

To examine the effectiveness of Classroom Performance System (CPS) technology integration, the third research question was:

Research Question 3:

> *Is Classroom Performance System (CPS) technology integration effective in terms of:*
> *(a) classroom environment?*
> *(b) student attitudes toward science?*

To investigate the differential effectiveness Classroom Performance System (CPS) technology integration for males and females, the fourth research question was:

Research Question 4:

> *Is Classroom Performance System (CPS) technology integration differentially effective for males and females in terms of:*
> *(a) classroom learning environment?*
> *(b) student attitudes toward science?*

3.3 Research Design

A quasi-experimental design was used in collecting quantitative data using two questionnaires. This design was selected because there wasn't a random assigning of students, and the variables within and among the classrooms could not be controlled

(Shulman, 1997). Convenience sampling was used because the class composition was determined by the school district and not the researcher (Punch, 1998).

The teachers and students were cooperative in terms of their willingness to participate in the study. The classes were selected because they are in the school where the researcher is a teacher and the teachers are the researcher's colleagues. The science units taught followed the guidelines for New York State in both the biology and earth science classrooms.

There was no control over the teaching methods used by teachers in their classrooms. The only variable controlled by the researcher was the usage or non-usage of Classroom Performance System (CPS) technology. Teachers who were a part of the experimental group were asked to incorporate this technology into their daily lessons, while teachers who were are part of the control group were instructed to teach as they normally would. The experimental group teachers in this study were acting as Teaching Self-Evaluators (see page 48). CPS technology was introduced to the teachers in a meeting as a part of a district initiative to incorporate more technology into daily lesson plans. During the meeting, teachers were given a brief introduction on how to use the CPS clickers, but the teachers were not provided with professional development on how to use the CPS clickers to improve their teaching strategies.

The survey, assessing student perceptions of their classroom learning environment and attitudes towards science, was administered to students on two separate occasions: the first was a pretest before the units were taught; and the second was a posttest at the culmination of the units. The survey was administered on two occasions to increase the comprehensiveness of the data available for analysis and in an effort to compare pretest and postest data. Although the survey could be administered using any computer with an internet connection, there was limited availability of computers in the building where the survey responses were collected. Therefore, surveys were administered using a mobile laptop cart shared by the entire science department. So, if students were absent from class on the days when the survey was administered, they did not submit responses on that day. As a result, there were many students who did not submit matched pretest and posttest survey responses. There were 971 students who submitted pretest surveys while only 389 students submitted posttest surveys. Therefore, it was not meaningful to compare pretest and posttest data with such a small sample of matched responses.

The surveys were administered to two distinct groups of students: the experimental group was taught by teachers integrating CPS clicker technology into daily lesson plans; and the control group was taught by teachers not integrating the technology. By having two distinct groups in this study, two different learning environments were established by the decisions of teachers to integrate CPS or not.

3.4 Instruments Selected to Collect Data

To answer the research questions outlined above, quantitative data were collected using a modified version of Technology-Rich Outcomes-Focused Learning Environments Inventory (TROFLEI) and the Attitude and Efficacy Questionnaire. Student perceptions of the classroom learning environment were measured using a modified version of the TROFLEI (Section 3.4.1 below) and the Attitude and Efficacy Questionnaire was used to assess student attitudes toward science and computers and their efficacy in science (Section 3.4.2).

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

The TROFLEI was chosen for assessing student perceptions of the learning environment (see detailed literature review in Section 2.2.2.10). There are 10 dimensions assessed with this instrument from two frames of reference: actual (what the student perceives is happening) and preferred (what the student wishes to happen). The actual and preferred versions are presented in a side-by-side format for ease of use (Aldridge & Fraser, 2008). The TROFLEI has been used in several studies in which learning environment outcomes were investigated in Australia (Aldridge, Dorman et al., 2004; Aldridge & Fraser, 2008, 2011; Dorman & Fraser, 2009), New Zealand (Koul et al., 2011) and the USA (Etzel, 2008).

In a study involving 1,249 students from Western Australia and Tasmania, Aldridge, Dorman and Fraser (2004) treated the actual and preferred forms of the TROFLEI as methods and the 10 scales of the TROFLEI as traits for their multitrait-multimethod modelling. The study revealed strong factorial validity and sound psychometric properties for the instrument, as well as a shared common structure for the actual and preferred forms (Aldridge, Dorman et al., 2004).

Aldridge and Fraser (2008, 2011) originally developed the TROFLEI to monitor and evaluate a new school focused on outcomes. In their study conducted over a four-year time period, Aldridge and Fraser detected changes in students' perceptions of their classroom learning environments. These changes supported the effectiveness of the outcomes-focused approach of the school. Data also revealed differences in perceptions between genders and between university-entrance examinations and wholly school-assessed subjects (Aldridge & Fraser, 2008, 2011).

The TROFLEI was used in a study of 4,146 high school students from Western Australia and Tasmania to examine the relationships between student affective outcomes and TROFLEI scales, gender, grade level and home computer and Internet access. The analysis suggested that the improvement of the classroom learning environment has the potential to improve student outcomes (Dorman & Fraser, 2009).

Koul, Fisher and Shaw (2011) used 1,027 responses to the TROFLEI from 30 classes in New Zealand to investigate differences between students' perception of their classroom learning environments as related to actual and preferred environments, year levels and gender. The identification of differences between the actual and preferred forms of the TROFLEI suggested that students participating in the study desired improvements in their learning environment. Both females and older students perceived their technology-rich learning environments more positively than did males and younger students (Koul et al., 2011).

In all of the studies conducted, the TROFLEI has shown satisfactory internal consistency reliability for both its preferred and actual versions (Aldridge, Dorman et al., 2004; Aldridge & Fraser, 2008, 2011; Dorman & Fraser, 2009; Koul et al., 2011). The TROFLEI, therefore was selected and used with confidence to assess the learning environment in the current study. In the current study, both the actual and preferred versions of the TROFLEI were administered in order to provide more comprehensive data for further validating the TROFLEI.

The TROFLEI incorporates all seven dimensions from the WIHIC described in Section 2.2.2.9 (Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Investigation, Cooperation and Equity), but also includes three additional scales that are important to an outcomes focus and technology use. These three scales are Differentiation, Computer Usage and Young Adult Ethos (Aldridge & Fraser, 2008). As noted in Section 2.2.2.9, the WIHIC has been used in a multitude of studies around the world and has consistently shown sound factorial validity and internal consistency reliability (Aldridge & Fraser, 2000; Chionh & Fraser, 2009; Dorman, 2003, 2008; Fraser, Aldridge, & Adolphe, 2010; Koul & Fisher, 2005).

Table 3.1 Scale Description and Sample Item for each TROFLEI Scale

Scale	Scale Description	Sample Item
Involvement	The extent to which students participate in class discussions	My ideas and suggestions are used during classroom discussions.
Task Orientation	The extent to which it is important to complete activities planned	I know what I am trying to accomplish in this class.
Investigation	The extent to which opportunities for inquiry activities are given	I carry out investigations to test my ideas.
Equity	The extent to which students perceive their equality in the classroom	I am treated the same as other students in this class.
Differentiation	The extent to which students different learning styles are addressed	I am given work that suits my ability.
Computer Usage	The extent to which computers are incorporated into the class	I use the computer to find out information about the course.
Young Adult Ethos	The extent to which students are treated as mature, responsible and reliable young adults	I am given responsibility.

Response alternatives for the five-item frequency scale include Almost Never, Seldom, Sometimes, Often and Almost Always. Adapted from Aldridge & Fraser (2008).

In this study, a modified seven-scale version of the TROFLEI was used (Appendix A), for which the three scales of Student Cohesiveness, Teacher Support, and Cooperation were omitted because of their limited relevance, as well as to reduce the time needed for administration of the survey to students. The scales used, with a scale description and sample item from each scale, are shown in Table 3.1. The modified TROFLEI has 56 items in eight scales. Students respond to items using a frequency scale of Almost Never, Seldom, Sometimes, Often, and Almost Always.

3.4.2 Attitude and Efficacy Questionnaire

To measure students' attitudes toward their science class, the Attitude and Efficacy Questionnaire was used (see detailed literature review in Section 2.2.3.1). Because attitude outcomes are often overlooked when researching outcomes related to classroom learning environment, Aldridge and Fraser (2008) developed the Attitude and Efficacy Questionnaire to assess Attitude to Subject, Attitude to Computer Use and Academic Efficacy. The questionnaire has 24 items (8 items per scale). The scales used, with an explanation and sample item for each, are shown in Table 3.2. Students respond to items using a frequency scale of Almost Never, Seldom, Sometimes, Often, and Almost Always.

Table 3.2 Scale Description and Sample Item for each Attitude and Efficacy Questionnaire Scale

Scale	Scale Description	Sample Item
Attitude to Subject	The extent to which students enjoy the subject	I enjoy lessons in this subject.
Attitude to Computer Use	The extent to which students enjoy using a computer	Working on a computer makes my work more enjoyable.
Academic Efficacy	The extent to which students are confident in their abilities in the subject	I am good at this subject.

Response alternatives for the five-item frequency scale are Almost Never, Seldom, Sometimes, Often and Almost Always.
Adapted from Aldridge & Fraser (2008).

As noted in Section 2.3.2, the Attitude to Subject items in the Attitude and Efficacy Questionnaire was adapted by Aldridge and Fraser (2008) from the frequently-used Enjoyment of Science Lessons Scale from TOSRA (Fraser, 1981). The Attitude to Computer Use items were adapted from the Computer Attitudes Survey (CAS) (Loyd & Gressard, 1984; Newhouse, 2001). The Attitude and Efficacy items were adapted from the Morgan-Jinks Student Efficacy Scale (MJSES) (Jinks & Morgan, 1999). The Attitude and Efficacy Questionnaire was found to be valid and reliable in several countries (Aldridge & Fraser, 2008; Etzel, 2008; Koul et al., 2011) and can therefore be used with confidence in the current study. This Attitude and Efficacy Questionnaire can be found in Appendix A as the final portion of the survey distributed to students.

3.5 Data Collection

The current study of the evaluation of Classroom Performance System (CPS) technology in terms of classroom environment and attitudes took place over two phases. The first phase involved a pilot study, conducted to ensure that the instruments were readable by the target audience (described in Section 3.5.1). The second phase involved the main study (described in Section 3.5.2).

3.5.1 Pilot Study

Before a researcher uses his or her questionnaire to answer research questions, it is important to pilot the instrument. "Pilot-testing will identify ambiguities in the instructions; it will help clarify the wording of questions, and it may alert you to omissions or unanticipated answers in multiple choice or ranking questions" (Anderson, 1998, p. 179). The pilot study should be conducted with about a dozen volunteers who can complete and critique a survey both individually and as a group. Volunteers for the pilot study can evaluate the instrument for effectiveness and the researcher can then make the appropriate adjustments and changes (Anderson, 1998).

To ensure that the questionnaires were readable and comprehensible for participants in this study, a pilot study was conducted. A pilot version of the questionnaire was administered to 40 high-school science students in three classes selected from one school located in New York. The students were asked to indicate areas that were confusing or unclear; all students were highly cooperative during the pilot study.

The students commented on any items and any wording that they found confusing. Adjustments based on student feedback were incorporated into the final instrument. Although the pilot study indicated that most of the items were understood by the majority of students, the distinction between the 'actual' and 'preferred' forms of the instrument caused a level of confusion for some students. When students asked what the difference was between these two forms, students were told that the 'actual' form describes how often each practice actually takes place in this class and the 'preferred' form describes how often they would like each practice to take place. Students understood this explanation and were able to answer the questionnaire based on this clarification. To reduce confusion during administration during the main study, this wording was explained by the teachers administering the TROFLEI.

The word 'seldom', that is used in the response scale, also caused some confusion. When students asked for a definition of the word 'seldom' they were told that it means 'rarely'.

3.5.2 Main Study

The purpose of this phase of the study was to collect the data needed to answer the research questions. The initial questionnaire, consisting of personal identification information (so that pretest and posttest questionnaire responses could be matched), a modified version of the TROFLEI and the Attitude and Efficacy Questionnaire, was administered prior to the main study. The TROFLEI was given in both its actual and preferred form in order to permit further validation of both forms of the questionnaire. Also, the TROFLEI was administered on two different occasions (as a pretest and a posttest) to improve the comprehensiveness of the validation of the instruments.

In this phase of the study, there were two instructional groups: classes that used CPS technology in an experimental group, and classes in a control group that did not. The teachers in the experimental group taught two designated units, which integrated CPS technology in order to embed assessment into daily lesson plans. These assessments were administered as brief formative assessments with multiple-choice questions taken from old New York State Regents examinations. The control group did not use CPS; teachers continued to teach without the use of CPS technology during the experimental period.

Regardless of whether the classes were taught with CPS integration, lessons focused on similar content that was centred on the curriculum. Aside from the CPS technology integration, all other classroom interactions were kept consistent. Students were assigned the same work, discussed the same lecture material, were assessed with the same examinations, received the same class work, and were responsible for the same content materials.

Students in both the experimental and control groups were given the same learning environment and attitude measures at the beginning and the culmination of studying the Cells and Cellular Respiration unit for biology and Astronomy and Weather unit for earth science.

3.6 Sample

This section discusses the sample of schools and students used in each phase of the present study, namely, the small pilot study and the main study. In the first phase of the study, a small sample in one New York high school was used to check readability of the questionnaire items. The items were administered to 40 students in grades 10 – 12 from three classes taught by the same teacher.

In the second phase of the study, modified versions of the TROFLEI and the Attitude and Efficacy Questionnaire were used to further validate the questionnaires and to investigate associations between students' perceptions of their classroom learning environment and their attitudes toward science. The sample involved all of the biology students and earth science students in one high school in New York State.

Seventeen teachers were involved in this study: 7 teachers teaching 22 sections of biology and 10 teachers teaching 35 sections of earth science. Six teachers were trained and involved in the experimental group for which CPS technology was integrated into two consecutive curriculum units. Of the 6 teachers in the experimental group, 2 teachers taught 7 biology sections and 4 teachers taught 13 earth science sections. The other 11 teachers were a part of the control group, with 5 teachers teaching 15 biology sections and 6 teachers teaching 22 earth science sections. Although the sample was from only one school, the enrollment in earth science and biology courses is heterogeneous and typical of many of the districts in New York State. However, generalizations should be made cautiously as the results are from students for a single school.

Teachers were assigned two dates for administering the survey. The first date was prior to the main study, whereas the second date was at the culmination of the main study. If students happened to be absent from class on the days when the survey was administered, then they were asked to complete the survey outside class time. Most students did not do this and, as a result, there were many students who did not provide both the pretest and posttest data requested by the researcher. The achieved sample size when the TROFLEI and Attitude and Efficacy Questionnaire were administered was 971 students for the pretest and 389 students for the posttest. If students were absent from class when the survey was administered on either occasion, then their pretest and posttest data were not able to be matched. In some cases, students neglected to finish the final section of the survey involving the Attitude and Efficacy Questionnaire. However, these responses were still used for validation of the modified version of the TROFLEI as students' responses were complete. Because there was such a difference in the two sample sizes, comparisons between the pretest and posttest data were not viable.

To answer the first research question concerning whether the instruments used in the study were valid and reliable, a sample of 971 student responses to a pretest and 389 student responses to a posttest was used. In validating questionnaires, students' responses to both actual and preferred versions of the TROFLEI, as well as to the Attitude and Efficacy Questionnaire, during both pretest and posttest administrations, were used.

To answer the second research question examining concerning relationships between students' perceptions of the classroom learning environment and student attitudes, the sample of 389 student responses to the posttest were used.

To answer the third and fourth research questions regarding the effectiveness of CPS technology integration and the differential effectiveness of CPS for males and females, the sample of 389 student responses to the posttest were used. The gender breakdown for this sample consisted of 179 males and 210 females. There were 178 students in the experimental group and 211 students in the control group.

3.7 Administration of Surveys

The TROFLEI and the Attitude and Efficacy Questionnaire were accessed electronically by students via a secure web link (www.surveymonky.com/meyercurtinphd) during the regular science class period (SurveyMonkey, 2011). This secure web link provided universal access to each student in the building and ensured that students answered every question before the survey could be submitted. Students and teachers reported no difficulty in using SurveyMonkey® to take the survey and found it user-friendly. To ensure consistency in the administration of the questionnaires, teachers were provided with detailed instructions about how to administer the surveys, as well as with the directions that they were required to explain and read to students. Teachers were asked to administer the surveys personally so that they could assist students with any questions that they had. The teacher of every biology and earth science class in the school was asked to take the survey. Classes from one school were chosen for convenience of the researcher, but this gave rise to potential limitations in the generalization of findings.

The privacy of all participants was preserved. Students were asked to record their student identification numbers on the survey for tracking purposes only; this information was eliminated from the record once raw data for pretests and posttests were matched. All data were stored in a secure location on an external hard drive. No participant was identified in the reporting of the study. The school district received the findings from the data analysis conducted by the researcher. However, individual teachers and students were not named.

Each student responding to the survey provided information regarding his or her name, student identification number, gender and teacher name. Student names and identification numbers were available to the researcher so that pretest and posttest data could be matched. Once the pretest and posttest data were matched, the students' identification information was removed to ensure that confidentiality was preserved.

3.8 Data Collection and Student Errors

Survey responses were collected and recorded using a Internet browser-based survey tool, SurveyMonkey® (SurveyMonkey, 2011). The design of this tool prevents some of the usual problems associated with data collection. The survey was set up with specific guidelines for response options to reduce typographical issues and incomplete surveys (because the survey was set up only to accept reasonable responses and to not register any survey until all responses in a section were completed).

The survey was designed to eliminate data-entry issues as much as possible. Whenever possible, drop-down menus and buttons were used as opposed to text entry to eliminate typographical errors. The survey was also designed so that responses to items could not be left blank. When students submitted their responses to each section, if there were items left blank, students were instructed to provide a response before the survey could be submitted. The survey was divided into three sections: student biographical and identification information; the modified TROFLEI; and the Attitude and Efficacy Questionnaire.

In some cases, students neglected to finish the final section of the survey involving the Attitude and Efficacy Questionnaire. These students' responses were still used for validation of the modified version of the TROFLEI as these students' surveys contained completed responses in that second section of the survey containing TROFLEI items.

Teachers were assigned two dates for administering the survey. The first date was prior to the main study. The second date was at the culmination of the main study. Although the survey was Internet browser-based, and available on any computer with Internet connection, computer availability was limited in the building where the survey responses were collected. On days when the survey was going to be administered by a teacher, the researcher delivered and set up a portable laptop cart containing 33 laptop computers. If students happened to be absent from class on the days when the survey was administered, they were encouraged to access and complete the survey outside class time. However, few students actually did this. As a result, there were many students who did not provide both the pretest and posttest data requested by the researcher.

3.9 Data Analysis

Data analyses were completed using the SPSS version 17 statistical package. This section describes the statistical analysis conducted to answer each research question.

3.9.1 Research Question 1: Validity and Reliability of Technology Rich Outcomes Focused Learning Environment Inventory (TROFLEI) and Attitude and Efficacy Scales

To examine the reliability and validity of the TROFLEI and Attitude and Efficacy scales when used with high-school students in the New York State, factor analysis, Cronbach alpha reliability, discriminant validity, and (for the actual form of the TROFLEI) ability to differentiate between the perceptions of students of different teachers were examined. This Section describes the validation of a modified version of the TROFLEI as well as the Attitude and Efficacy Questionnaire.
Factor analysis was used to determine whether the 56 items selected from the TROFLEI measured seven independent dimensions of the learning environment: Involvement, Task Orientation, Investigation, Equity, Differentiation, Computer Usage and Young Adult Ethos. Principal axis factor analysis with varimax rotation and Kaiser normalization was conducted for four sets of data; both actual and preferred versions of the TROFLEI were analyzed for both pretest and posttest data. Only items with factor loadings of at least 0.40 on their a priori scales and less than 0.40 on the other TROFLEI scales were retained.

Factor analysis was also used to determine whether the 24 items in the Attitude and Efficacy Questionnaire measured three independent dimensions (Attitude to Subject, Attitude to Computers and Student Self Efficacy). Principal axis factor analysis with varimax rotation and Kaiser normalization was again conducted for both the pretest and posttest data sets. Again, only items with factor loadings of at least 0.40 on their a priori scales and less than 0.40 on the other two attitude scales were retained.

The internal consistency reliability was examined using the Cronbach alpha coefficient in order to determine if the items in each of the seven scales selected from the TROFLEI and the three scales from the Attitude and Efficacy Questionnaire assessed a similar construct.

The discriminant validity of each scale was estimated using the mean correlation of each scale with the other scales as a convenient index. Discriminant validity indicates the extent to which each scale of the TROFLEI or Attitude and Efficacy Questionnaire measures a unique dimension. Four data sets for the TROFLEI (both pretest and posttest responses to the actual and preferred versions) and the two data sets for the Attitude and Efficacy Questionnaire (both pretest and posttest) were used in this discriminant validity analysis.

Analysis of variance (ANOVA) was used to check the ability of each scale in the actual version of the TROFLEI to differentiate between the perceptions of students with different teachers. ANOVA results indicated whether students with the same teacher perceived the learning environment similarly, while perceptions of students with different teachers varied. The eta^2 statistic from ANOVA was calculated for the actual form of the TROFLEI for both the pretest and postest data as a measure of the proportion of variance explained by differences between teachers.

3.9.2 Research Question 2: Associations Between Learning Environment and Student Attitude Toward Science

This study explored associations between students' perceptions of the learning environment and student attitudes toward science. Simple correlation and multiple regression analyses were used to examine the relationships between student perceptions of the classroom environment and student attitudes. Simple correlation was used to examine the bivariate relationship between each attitude scale and each environment scale of the TROFLEI. Multiple regression analysis was carried out to examine the joint influence of the whole set of environment scales on each attitude scale, as well as to identify which environment scales contributed to variance in students' attitudes when other environment scales were mutually controlled. The objective of this analysis was to identify which of the six scales of the TROFLEI contributed most to the multivariate associations between learning environment and student attitudes. Standardized regression weights were examined to identify which learning environment scales accounted for a statistically significant amount of variance in student attitudes.

3.9.3 Research Questions 3 & 4: Effectiveness of CPS Technology Integration and Differential Effectiveness of CPS for Males and Females

The effectiveness of Classroom Performance System (CPS) technology integration in this study was investigated using effect sizes and a two-way MANOVA/ANOVA for differences between the experimental and control groups in student perceptions of the learning environment and attitudes using the individual student as the unit of analysis. In the two-way MANOVA, the dependent variables were the scales from the TROFLEI and Attitude and Efficacy Questionnaire and the two independent variables were the method of instruction (CPS versus non-CPS) and student gender. Because the multivariate test from MANOVA using Wilks' lambda criteria yielded a statistically significant result overall, the individual two-way ANOVA was interpreted separately for each learning environment and attitude scale. The sample consisted of 389 students' posttest responses.

The two-way MANOVA was also used to explore the differential effectiveness of the use of CPS for males and females. The interaction of the use/non-use of CPS technology integration with gender provided information about the differential effectiveness of CPS integration for males and females for each learning environment and attitude scale.

In addition to using MANOVA to ascertain statistical significance, effect sizes (Cohen, 1988) were used to indicate the magnitude of effects. In particular, the difference between the two instructional groups (CPS and non-CPS) for each dependent variable was expressed in standard deviation unis using Cohen's *d* statistic (the difference between means divided by the pooled standard deviation).

3.10 Summary

The current study took place in two phases, which were described in this chapter. The pilot phase involved checking the readability of a modified version of the TROFLEI and Attitude and Efficacy Questionnaire with a group of 40 high-school students. Aims of the study were to validate the instruments used, investigate the associations between learning environments and student attitudes, and examine the effectiveness of CPS technology integration as well as its differential effectiveness for males and females.

Two instruments were used in the collection of quantitative data. A modified version of the Technology-Rich Outcomes-Focused Learning (TROFLEI) was used to assess student perceptions of eight aspects of the learning environment (namely, Involvement, Task Orientation, Investigation, Cooperation and Equity, Differentiation, Computer Usage and Young Adult Ethos). The Attitude and Efficacy Questionnaire was used to assess student attitudes (Attitude to Subject, Attitude to Computers and Self Efficacy).

Validation of the instruments used in this study was based on data collected from a large school district in New York State. The sample consisted of 17 teachers: 7 teachers teaching 22 sections of biology and 10 teachers teaching 35 sections of earth science. The experimental group consisted of 6 teachers who were trained and integrated CPS technology into two consecutive curriculum units (2 teachers taught 7 biology sections and 4 teachers taught 13 earth science sections). The other 11 teachers were a part of the control group (5 teachers teaching 15 biology sections and 6 teachers teaching 22 earth science sections). There were 971 students who responded to the pretest survey and 389 students who responded to the posttest survey.

Factor analysis, Cronbach alpha reliability, discriminant validity and the ability to differentiate between the perceptions of students of different teachers were used to provide further evidence of scale validity and reliability for the four sets of data for the pretest and posttest versions of the actual version of the TROFLEI and the two data sets for the pretest and posttest version of the Attitude and Efficacy Questionnaire. Results of these analyses appear in the next chapter in Section 4.2.

Associations between the learning environment and student attitudes were examined with the sample of 389 students responding to the posttest administration of the survey. Simple correlation and multiple regression analyses were used to examine, respectively, the bivariate and multivariate relationships between classroom learning environment and attitudes. Regression coefficients were used to identify which learning environment scales were significantly related to an attitude dimension when all other TROFLEI scales were mutually controlled. Results of these analyses appear in Section 4.3.

The main study used data collected from 389 students with 17 different teachers with two different modes of instruction; 6 teachers were a part of the experimental group (CPS) and 11 teachers were a part of the control group (non-CPS). The effectiveness of CPS technology in terms of the learning environment and attitudes toward science was investigated using two-way MANOVA with the TROFLEI scales and Attitude and Efficacy scales as the dependent variables. The method of instruction (use or non-use of CPS) and student gender were the independent variables. Because the MANOVA using the Wilks' lambda criterion showed significant differences for the set of dependent variables, the univariate ANOVA was interpreted for each learning environment (TROFLEI) and attitude (Attitude and Efficacy Questionnaire) scale. In order to investigate the magnitudes of the differences between instructional groups, as well as their statistical significance, effect sizes were calculated as recommended by Cohen (1988). The effect size, which was calculated by dividing the difference between the means of the two instructional groups by the pooled standard deviation, expresses the difference between groups in standard deviation units. MANOVA also was used to examine the differential effectiveness of CPS use/non-use for males and females, with the interaction between the use/non-use of CPS and gender being used to identify the presence of differential effectiveness. Results of these analyses appear in Section 4.4.

In Chapter 4, results of data analyses are reported and the research questions are answered.

Chapter 4
Data Analyses and Results

4.1 Introduction

This chapter describes data analyses and reports findings for the quantitative data collected using a modified version of the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) and the Attitude and Efficacy Questionnaire. To examine the reliability and validity of the TROFLEI and Attitude and Efficacy scales, factor analysis, Cronbach alpha reliability, discriminant validity, and (for the TROFLEI only) ability to differentiate between the perceptions of students with different teachers were examined. Simple correlation and multiple regression analysis were used to explore the relationships between student perceptions of the classroom environment and student attitudes. The effectiveness of the use/non-use of Classroom Performance System (CPS) technology integration, as well as interactions between the use/non-use of CPS technology integration and gender to provide information about the differential effectiveness of CPS integration for males and females, was investigated using a two-way MANOVA.

A survey combining a modified version of the TROFLEI and Attitude and Efficacy Questionnaire was administered to 971 students during the pretest and 389 students during the posttest (as described in Section 3.6.2). There were 17 teachers involved in the study. The survey was administered to the classes of 7 teachers teaching 22 sections of biology and to the classes of 10 teachers teaching 35 sections of earth science. All of the students were from one high school (grades 9 – 12) in New York State. There was attrition in the number of responses between pretest and posttest data because of absences during the posttest administration.

All survey responses were used to validate both instruments contained in the survey and to determine any associations between student attitudes and the learning environment, while only the posttest responses were used to investigate effectiveness of CPS technology integration on the classroom learning environment as well as the differential effectiveness of CPS integration for males and females.

This chapter describes the data analysis conducted in the present study in terms of: the validity of the instruments used (Section 4.2); associations between learning environment and attitudes (Section 4.3); and the effectiveness of CPS technology integration on learning environment and student attitudes and the differential effectiveness of using CPS for males and females (Section 4.4).

4.2 Validity and Reliability of Modified Version of TROFLEI and Attitude and Efficacy Questionnaire

To answer the first research question below, modified versions of the TROFLEI and the Attitude and Efficacy Questionnaire were administered to 971 students at pretesting and 389 students at posttesting.

> Research Question 1: Are the following questionnaires valid when used with a sample from a large school district in New York State
> (a) a modified version of the TROFLEI?
> (b) the Attitude and Efficacy Questionnaire?

This section reports analyses including the factor structure of a modified version of the TROFLEI (4.2.1) and Attitude and Efficacy Questionnaire (4.2.2), the internal consistency reliability (4.2.3) and discriminant validity of the TROFLEI and Attitude and Efficacy Questionnaire (4.2.4), the ability of the TROFLEI to differentiate between the students of different teachers (4.2.5), and the consistency of validity results with past research (4.2.6).

4.2.1 Factor Structure of Modified Version of TROFLEI

To examine the internal structure of the 56-item, seven-scale version of the TROFLEI (assessing Involvement, Task Orientation, Investigation, Equity, Differentiation, Computer Usage and Young Adult Ethos; see Section 3.4.1) when used with high-school students in New York, principal axis factoring with varimax rotation and Kaiser normalization was used. In order to be retained, each item had to have a factor loading of at least 0.40 on its a priori scale and less than 0.40 on all other TROFLEI scales. This factor analysis was performed separately for four different data sets created by administering both the actual and preferred versions of the TROFLEI during both a pretest and posttest.

Table 4.1 provides the factor loading for each item on each TROFLEI scale. Item numbers shown in the table are listed in the order in which they appear in the survey that was administered to students (Appendix A). Table 4.1 indicates that the optimal factor solution existed for the four data sets by retaining 46 of the original 56 items. All items that were retained had a factor loading of at least 0.40 on their a priori scale, ranging from 0.42 to 0.84, and less than 0.40 on all other scales. Items that were deleted were the entire Differentiation scale, Item 7 from the Involvement scale and Item 8 from the Computer Usage scale. Removal of these items improved the internal consistency reliability and factorial validity. The optimal factor solution occurred for a six-scale, 46-item version of the TROFLEI.

Table 4.1 also reports the percentage of variance and eigenvalues for each scale for each of the four data sets. The percentage of variance for the pretest actual version of the TROFLEI ranged from 3.49% to 27.08% for different scales, with a total variance of 29.22%. The eigenvalues ranged from 1.64 to 12.72. The percentage of variance for the pretest preferred version of the TROFLEI ranged from 3.31% to 31.05% for different scales, with a total variance of 29.71%. The eigenvalues ranged from 1.55 to 14.59. The percentage of variance for the posttest actual version of the TROFLEI ranged from 2.92% to 32.7% for different scales, with a total variance of 30.47%. The eigenvalues ranged from 1.40 to 15.69. The percentage of variance for the posttest preferred version of the TROFLEI ranged from 1.73% to 35.99% for different scales, with a total variance of 30.56%. The eigenvalues ranged from 1.39 to 17.27. The results of the factor analysis, shown in Table 4.1, strongly support the factorial validity of the TROFLEI for the sample of high-school students in New York.

Table 4.1 Factor Analysis Results for Actual and Preferred TROFLEI Scales for Pretest and Posttest

Item	Involvement				Task Orientation				Investigation				Equity				Computer Usage				Young Adult Ethos			
No	Pre		Post		Pre		Post		Pre		Post		Pre		Post		Pre		Post		Pre		Post	
	Act	Pref	Act	Pref	Act	Pref	Act	Pref	Act	Pref	Act	Pref	Act	Pref	Act	Pref	Act	Pref	Act	Pref	Act	Pref	Act	Pref
Invol 1	0.68	0.64	0.74	0.65																				
Invol 2	0.71	0.65	0.77	0.76																				
Invol 3	0.44	0.49	0.48	0.50																				
Invol 4	0.61	0.64	0.68	0.68																				
Invol 5	0.52	0.44	0.57	0.47																				
Invol 6	0.49	0.52	0.56	0.63																				
Invol 8	0.42	0.48	0.50	0.50																				
TO 1					0.61	0.64	0.60	0.62																
TO 2					0.55	0.59	0.52	0.69																
TO 3					0.55	0.65	0.58	0.72																
TO 4					0.56	0.68	0.55	0.66																
TO 5					0.64	0.69	0.63	0.78																
TO 6					0.56	0.70	0.56	0.66																
T0 7					0.57	0.68	0.61	0.69																
TO 8					0.62	0.66	0.64	0.71																
Inves 1									0.63	0.57	0.57	0.57												
Inves 2									0.47	0.55	0.47	0.55												
Inves 3									0.73	0.70	0.73	0.77												
Inves 4									0.61	0.63	0.59	0.61												
Inves 5									0.70	0.71	0.69	0.73												
Inves 6									0.69	0.71	0.71	0.76												
Inves 7									0.71	0.75	0.73	0.72												
Inves 8									0.62	0.66	0.67	0.68												
EQ 1													0.64	0.57	0.61	0.48								
EQ 2													0.71	0.64	0.69	0.62								
EQ 3													0.69	0.64	0.74	0.66								
EQ 4													0.75	0.72	0.78	0.69								
EQ 5													0.71	0.72	0.76	0.65								
EQ 6													0.69	0.71	0.72	0.68								
EQ 7													0.65	0.60	0.68	0.56								
EQ 8													0.72	0.69	0.72	0.59								
CU1																	0.58	0.59	0.60	0.55				
CU2																	0.75	0.75	0.76	0.77				
CU 3																	0.77	0.78	0.81	0.83				
CU 4																	0.72	0.74	0.71	0.69				
CU 5																	0.79	0.80	0.84	0.83				
CU 6																	0.79	0.80	0.83	0.78				
CU 7																	0.55	0.56	0.64	0.63				
YAE 1																					0.65	0.61	0.67	0.71
YAE2																					0.68	0.60	0.74	0.67
YAE 3																					0.55	0.59	0.59	0.67
YAE 4																					0.65	0.64	0.73	0.70
YAE 5																					0.57	0.62	0.68	0.70
TAE 6																					0.67	0.66	0.66	0.66
YAE 7																					0.69	0.68	0.72	0.72
YAE 8																					0.56	0.57	0.64	0.61
% Variance	3.49	3.31	2.92	2.91	3.77	11.28	3.73	35.99	12.18	6.43	5.99	6.04	27.08	31.05	32.7	1.73	4.15	3.48	4.31	3.94	6.58	4.42	14.65	13.31
Eigenvalue	1.64	1.55	1.40	1.39	1.77	5.30	1.79	17.27	5.72	3.02	2.87	2.90	12.72	14.59	15.69	3.60	1.95	1.64	2.06	1.89	3.09	2.08	7.03	6.39

Principal axis factor analysis with varimax rotation and Kaiser normalization. Factor loadings less than 0.04 have been omitted. Items Invol 7 and CU 8 were omitted. The entire Differentiation scale was removed to achieve optimal factor solution.
N=971 students at pretesting and 389 students at posttesting (17 teachers)

4.2.2 Factor Structure of Attitude and Efficacy Questionnaire

To assess student attitudes and self efficacy, the Attitude and Efficacy Questionnaire was used. This instrument contains 24 items, with eight items in each of the three scales of Attitude to Subject, Attitude to Computers and Self Efficacy (see Section 3.4.2). To examine the internal structure of the Attitude and Efficacy Questionnaire, a principal axis factor analysis was conducted separately for pretest and posttest data. Table 4.2 contains the factor loadings for the Attitude and Efficacy Questionnaire. Item numbers shown in the table are listed in the order in which they appear in the survey administered to students (Appendix A).

Table 4.2 Factor Analysis Results for Attitude and Efficacy Questionnaire

Item	Attitude to Subject		Attitude to Computers		Self Efficacy	
	Pre	Post	Pre	Post	Pre	Post
Subject 1	0.79	0.78				
Subject 2	0.84	0.83				
Subject 3	0.87	0.86				
Subject 4	0.83	0.84				
Subject 5	0.75	0.77				
Subject 6	0.89	0.88				
Subject 7	0.77	0.77				
Subject 8	0.84	0.85				
Computers 1			0.69	0.74		
Computers 2			0.80	0.86		
Computers 3			0.77	0.79		
Computers 4			0.74	0.78		
Computers 5			0.85	0.82		
Computers 6			0.84	0.84		
Computers 7			0.46	0.61		
Computers 8			0.53	0.67		
Self Efficacy 1					0.80	0.76
Self Efficacy 2					0.86	0.81
Self Efficacy 3					0.67	0.68
Self Efficacy 4					0.84	0.82
Self Efficacy 5					0.78	0.79
Self Efficacy 6					0.74	0.59
Self Efficacy 7					0.59	0.52
Self Efficacy 8					0.56	0.64
% Variance	34.88	40.99	14.77	16.77	16.66	11.54
Eigenvalue	8.37	9.83	3.54	4.02	3.99	2.77

Principal axis factor analysis with varimax rotation and Kaiser normalization.
Factor loadings less than 0.04 have been omitted.
N=919 students at pretesting and 389 students at posttesting (17 teachers)

A principal axis factor analysis with varimax rotation and Kaiser normalization indicated that all items had factor loadings of at least 0.40 on their a priori scales and less than 0.40 on the other two attitude scales, for both pretest and posttest (see Table 4.2). Therefore, all 24 items were retained.

The percentage of the total variance extracted with each factor is also recorded at the bottom of Table 4.2. For the Attitude and Efficacy Questionnaire pretest, the percentage of variance varied from 14.77% to 34.88% for different scales, with the total variance accounted for being 18.10%. For the posttest, the percentage of variance varied from 11.54% to 40.99% for different scales, with the total variance accounted for being 18.30%. The eigenvalues ranged from 3.54 to 8.37 for the pretest and from 2.77 to 9.83 for the posttest. The results of the factor analysis shown in Table 4.2 strongly support the factorial validity of the Attitude and Efficacy Questionnaire for the sample of 919 student responses to the pretest and 389 student responses to the posttest.

4.2.3 Internal Consistency Reliability of a modified version of the TROFLEI and Attitude and Efficacy Questionnaire

The Cronbach alpha reliability coefficient used was an index of scale internal consistency. Internal consistency reliability is a measure of the extent to which items in a scale measure the same construct. Table 4.3 shows the scale reliability estimates for the TROFLEI ranged from 0.82 to 0.92 for the pretest actual version, from 0.83 to 0.92 for the pretest preferred version, from 0.86 to 0.94 for the posttest actual version and from 0.86 to 0.94 for the posttest preferred version.

The internal consistency reliability of the 24 Attitude and Efficacy Questionnaire items ranged from 0.89 to 0.95 for the pretest and from 0.91 to 0.96 for the posttest.

4.2.4 Discriminant Validity of modified version of TROFLEI and Attitude and Efficacy Questionnaire

To ensure that each of the individual scales of the TROFLEI and Attitude and Efficacy Questionnaire measures a unique dimension, discriminant validity was examined. Discriminant validity is the degree to which scales that should not be related to one another are actually unrelated. The mean correlation of each scale with the other scales was used as a convenient index of discriminant validity. Table 4.3 provides the results of these analyses.

The discriminant validity results indicate that most scales were fairly unique in the dimension that each assessed. For the TROFLEI, Table 4.3 shows that the mean correlation of a scale with the other scales varied from 0.18 to 0.41 for the pretest

Table 4.3 Average Item Mean, Average Item Standard Deviation, Internal Consistency Reliability (Cronbach Alpha Coefficient), Discriminant Validity (Mean Correlation with Other Scales) and Ability to Differentiate between Teachers (ANOVA Results)

Scale	No of Items	Version	Mean		SD		Alpha Reliability		Mean Correlation		ANOVA Results Eta^2	
			Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Learning Environment												
Involvement	7	Act	3.00	3.04	0.79	0.84	0.82	0.86	0.37	0.39	0.03**	0.06
		Pref	3.21	3.19	0.83	0.85	0.83	0.86	0.45	0.44		
Task Orientation	8	Act	4.05	4.00	0.70	0.82	0.85	0.92	0.39	0.45	0.03**	0.17***
		Pref	4.35	4.29	0.75	0.84	0.91	0.94	0.44	0.47		
Investigation	8	Act	3.01	3.04	0.92	0.89	0.90	0.91	0.41	0.43	0.03**	0.07**
		Pref	3.36	3.31	0.98	0.97	0.91	0.93	0.48	0.47		
Equity	8	Act	3.97	3.95	0.95	0.97	0.92	0.94	0.35	0.39	0.05***	0.13***
		Pref	4.17	4.13	0.87	0.89	0.92	0.93	0.44	0.47		
Computer Usage	7	Act	2.31	2.44	0.94	1.02	0.87	0.89	0.18	0.16	0.03**	0.09***
		Pref	2.74	2.79	1.04	1.02	0.89	0.89	0.26	0.21		
Young Adult Ethos	8	Act	3.96	3.97	0.82	0.87	0.89	0.93	0.38	0.42	0.02	0.12***
		Pref	4.15	4.11	0.80	0.85	0.90	0.93	0.47	0.46		
Attitudes												
Attitude to Subject	8		2.71	2.74	0.97	1.01	0.95	0.96	0.31	0.39		
Attitude to Computers	8		2.04	2.03	0.77	0.81	0.89	0.92	0.23	0.34		
Student Self Efficacy	8		2.66	2.68	0.90	0.91	0.91	0.91	0.28	0.43		

** $p<0.01$, *** $p<0.001$

N=971students at pretesting and 389 students at posttesting (17 teachers) actual version, from 0.26 to 0.48 for the pretest preferred version, from 0.16 to 0.45 for the posttest actual version and from 0.21 to 0.47 for the posttest preferred version.

For the Attitude and Efficacy Questionnaire, the mean correlation of a scale with the other scales varied from 0.23 to 0.31 for the pretest and from 0.34 to 0.43 for the posttest administration, as reported in Table 4.3. These results, with support from the factor analyses, suggest that each scale of both instruments measures a relatively unique dimension.

4.2.5 Ability of Modified Version of TROFLEI to Differentiate Between Students of Different Teachers

To determine the degree to which the actual version of each TROFLEI scale was able to differentiate between the perceptions of students of different teachers, a one-way analysis of variance (ANOVA) was computed. The independent variable was the teacher (N=17 teachers). The ANOVA results reported in Table 4.3 show that most TROFLEI scales differentiated significantly between students with different teachers ($p<0.01$). Students with the same teacher perceived the environment in a relatively similar manner, while the mean perceptions of students with different teachers varied.

The proportion of variance accounted for by different teachers was calculated using the eta^2 statistic for the actual form of the TROFLEI for both the pretest and postest. The amount of variance in scores accounted for by different teachers for the pretest ranged from 0.02 to 0.05 and was statistically significant for all scales except Young Adult Ethos, suggesting that learners perceived the learning environments of different teachers differently for Involvement, Task Orientation, Investigation, Equity and Computer Usage. The eta^2 statistic for the posttest ranged from 0.06 to 0.17 and was statistically significant for all scales except Involvement, suggesting that students with different teachers perceived Task Orientation, Investigation, Equity, Computer Usage and Young Adult Ethos differently.

4.2.6 Consistency of Validity Results with Past Research

The validity results for the current study are similar to those in other validation studies involving the TROFLEI and Attitude and Efficacy Questionnaire in terms of factorial validity, internal consistency reliability, discriminant validity, and (for the

TROFLEI) ability to differentiate between the perceptions of students in different classrooms or with different teachers. Comparable validity results for the TROFLEI have been reported for large samples in Australia (Aldridge, Dorman et al., 2004; Aldridge & Fraser, 2008; Aldridge, Fraser, & Fisher, 2003; Dorman & Fraser, 2009), for New Zealand students (Koul et al., 2011), and for the USA (Etzel, 2008). Additionally, many past studies have provided strong validity evidence for the questionnaire (namely, What Is Happening In this Class?, WIHIC) on which the TROFLEI was largely based, including samples from Singapore (Chionh & Fraser, 2009; Khoo & Fraser, 2008), the USA (den Brok et al., 2006; Martin-Dunlop & Fraser, 2007; Ogbuehi & Fraser, 2007; Wolf & Fraser, 2008) and Taiwan and Australia (Aldridge & Fraser, 2000). Although the Attitude and Efficacy Questionnaire has been used less frequently than the TROFLEI in past research, nevertheless, strong validity support has been reported for samples in Australia (Aldridge & Fraser, 2008) and New Zealand (Koul et al., 2011).

4.3 Associations Between Learning Environment and Attitudes

The second research question involved relationships between TROFLEI and Attitude and Efficacy Questionnaire scales:

> Research Question 2: Are there associations between classroom learning environment and student attitudes toward science?

In the current study, an exploration of associations between students' perceptions of the learning environment and student attitudes toward science was conducted. Simple correlation and multiple regression analyses were used to examine the relationships between student perceptions of the classroom environment and the student attitudes. Simple correlations were used to describe the bivariate relationship between each student attitude and each environment scale of the TROFLEI. Multiple regression analysis was carried out to examine the joint influence of the whole set of correlated environment scales on each attitude outcome, as well as which individual environment scales contributed to variance in students' attitudes when all other environment scales were mutually controlled. All analyses were performed separately for pretest and posttest data.

Table 4.4 shows the results of the correlation analyses used to investigate associations between the six learning environment scales and three student attitude scales. Most of the six scales of the TROFLEI were positively and significantly ($p<0.05$) correlated with each student attitude scale for both the pretest and posttest data. Exceptions were Computer Usage with Attitude to Computers for both pretest and posttest data.

The multiple correlation between the six learning environment scales of the TROFLEI and each of the three scales from the Attitude and Efficacy Questionnaire is shown at the bottom of Table 4.4 separately for pretest and posttest data. For Attitude to Subject, the multiple correlation was 0.45 for pretest responses and 0.35 for posttest responses. For Attitude to Computers, the multiple correlation was 0.24 for the pretest and 0.33 for the posttest. For Self Efficacy, the multiple correlation was 0.30 for the pretest and 0.40 for the posttest. These multiple correlations were all statistically significant, indicating that there were associations between the whole set of learning environment scales (Involvement, Task Orientation, Investigation,

Table 4.4 Simple Correlation and Multiple Regression Analyses for Associations between Student Attitudes and Learning Environments for Pretest and Posttest

Scale	Testing	Attitude-Environment Associations					
		Attitude to Subject		Attitude to Computers		Self Efficacy	
		r	β	r	β	r	β
Involvement	Pre	0.34**	0.13**	0.14**	0.06	0.23**	0.11**
	Post	0.24**	0.06	0.18**	0.06	0.29**	0.13*
Task Orientation	Pre	0.33**	0.11*	0.18**	0.04	0.27**	0.19***
	Post	0.18**	0.14	0.26**	0.08	0.32**	0.25***
Investigation	Pre	0.37**	0.18***	0.14**	0.02	0.21**	0.03
	Post	0.28**	0.20**	0.15**	0.05	0.33**	0.14*
Equity	Pre	0.27**	0.06	0.28**	0.04	0.16**	0.00
	Post	0.25**	0.26***	0.25**	0.05	0.17**	0.16*
Computer Usage	Pre	0.18**	0.05	0.03	0.02	0.10**	0.04
	Post	0.14**	0.05	0.07	0.05	0.12*	0.01
Young Adult Ethos	Pre	0.30**	0.09*	0.22**	0.15**	0.18**	0.03
	Post	0.19**	0.01	0.31**	0.20**	0.26**	0.10
Multiple Correlation, R	Pre		0.45***		0.24***		0.30***
	Post		0.35***		0.33***		0.40***

*$p<0.05$, **$p<0.01$, ***$p<0.001$

Equity, Computer Usage and Young Adult Ethos) and each of the three attitude scales (Attitude to Subject, Attitude to Computers and Student Self Efficacy).

To identify which environment scales made the largest contribution to explaining variance in attitudes outcomes, the regression weights were examined to identify any that were significantly greater than zero. Essentially, regression weights describe the influence of a learning environment scale on a student attitude scale when all of the other environment variables in the analysis are mutually controlled.

Table 4.4 indicates that four of the six TROFLEI scales uniquely accounted for a significant ($p<0.05$) amount of variance in student pretest attitudes toward their subject (Involvement, Task Orientation, Investigation and Young Adult Ethos). Only two of the six TROFLEI scales uniquely accounted for a significant ($p<0.05$) amount of variance in student posttest attitudes toward their subject (Investigation and Equity). The standardized regression weights reported in Table 4.4 indicate that only the Young Adult Ethos scale accounted for a significant ($p<0.05$) amount of variance in student attitudes toward computer usage for both the pretest and posttest when all other TROFLEI scales were mutually controlled. According to the standardized regression weights reported in Table 4.4, two of the six TROFLEI scales accounted for a significant amount of variance in the pretest efficacy (Involvement and Task Orientation) and four of the six TROFLEI scales accounted for a significant amount of variance in the posttest efficacy (Involvement, Task Orientation, Investigation and Equity) beyond that attributable to other TROFLEI scales.

Because all statistically significant relationships in Table 4.4 were positive, this suggests a positive link between students' attitudes and aspects of outcomes-focused learning environments assessed by the TROFLEI.

4.4 Two-Way MANOVA for Differences Between Instructional Groups and Genders in Terms of Learning Environment and Attitudes

The sample of 389 students from the posttest administration of the surveys was used to investigate differences between instructional groups and genders in terms of learning environment and attitudes. This sample was comprised of 178 students in the experimental group and 211 students in the control group; of these participants, 179 were male students and 210 were females students. The analysis involved a two-way MANOVA with the TROFLEI scales and attitude scales as the dependent variables. The two independent variables were the instructional method (CPS and non-CPS) and student gender. Differential effectiveness was considered to exist if there was a significant instruction-by-gender interaction for a particular dependent variable. Because the MANOVA using the Wilks' lambda criterion showed significant differences for the set of dependent variables as a whole, the univariate ANOVA was interpreted for each individual environment and attitude scale (Table 4.5).

Table 4.5 Two-Way MANOVA Results for Instruction and Gender Differences for Learning Environment and Attitude Scales

	Instruction		Gender		Instruction x Gender	
Scale	*F*	Eta^2	*F*	Eta^2	*F*	Eta^2
Learning Environment						
Involvement	0.04	0.00	0.00	0.00	0.60	0.00
Task Orientation	0.00	0.00	4.40**	0.02	0.91	0.00
Investigation	0.01	0.00	0.04	0.00	1.16	0.01
Equity	4.42**	0.02	0.18	0.00	0.32	0.00
Computer Usage	0.15	0.00	1.38	0.01	4.63**	0.02
Young Adult Ethos	1.07	0.00	0.74	0.00	0.31	0.00
Attitudes						
Attitude to Subject	0.09	0.00	6.08*	0.03	0.01	0.00
Attitude to Computers	0.02	0.00	0.78	0.00	0.31	0.00
Self Efficacy	2.62	0.01	2.19	0.01	1.27	0.01

N = 179 males and 210 females
**p<0.01

Table 4.5 shows that the two-way MANOVA and ANOVAs revealed statistically significant results (p<0.05) in four cases. There were significant differences for instructional method (CPS/non-CPS) for Equity, significant gender differences for Task Orientation and Attitude to Subject and a significant instruction x gender interaction for Computer Usage.

The following sections contain further discussion of the results in Table 4.5. Section 4.4.1 is a discussion of the effectiveness of Classroom Performance System (CPS) technology integration in terms of learning environment and attitudes, Section 4.4.2 discusses gender differences in learning environment perceptions and attitudes, and Section 4.4.3 is a discussion of the differential effectiveness of CPS for males and females in terms of learning environment and attitudes. The two-way MANOVA analyses are linked to research questions 3 and 4.

4.4.1 Effectiveness of Classroom Performance System (CPS) in Terms of Classroom Environment and Student Attitudes

The comparison of a CPS group and a non-CPS group, constituted the third research question:

> <u>Research Question 3</u>: Is Classroom Performance System (CPS) technology integration effective in terms of:
>
> (a) classroom environment?
>
> (b) student attitudes toward science?

The effectiveness of Classroom Performance System (CPS) technology integration in this study was investigated using effect sizes and the MANOVA/ANOVA results from Table 4.5 for differences between the experimental and control groups in student perceptions of the learning environment and attitudes using the individual student as the unit of analysis. Table 4.6 reports the average item mean, average item standard deviation, and effect size for each of the scales of the TROFLEI and Attitude and Efficacy Questionnaire for 389 posttest respondents. The F values presented in Table 4.6 are repeated from the two-way MANOVA displayed in Table 4.5.

Differences between the two instructional groups were statistically significant only for one scale, namely, Equity. The average item mean, which is the scale mean divided by the number of items in that scale, was 4.07 for the experimental group and 3.86 for the control group for the Equity scale. In other words, students involved in the experimental group perceived more equity than students in the control group not using CPS clickers.

To examine the magnitudes of the differences between instructional group, in addition to their statistical significance, effect sizes were calculated in terms of the differences in means divided by the pooled standard deviation. According to Cohen (1988), for behavioral sciences, an effect size of 0.01 to 0.23 can be considered small, of 0.24 to 0.36 is modest, and of 0.37 or greater is a large effect size. The effect size for Equity was relatively small with a value of 0.21 standard deviations. This result suggests that differences in perceptions of Equity in the classroom learning environment between students using CPS clickers and students who were not using the clickers were relatively small (although still statistically significant).

Table 4.6 Average Item Mean, Average Item Standard Deviation and Difference Between Instructional Groups (ANOVA Result and Effect Size) for Each Learning Environment and Attitude Scale

Scale	Average Item Mean		Average Item SD		Difference	
	Experimental	Control	Experimental	Control	*F*	Effect Size
Learning Environment						
Involvement	3.05	3.03	0.85	0.82	0.04	0.02
Task Orientation	4.01	4.00	0.74	0.88	0.01	0.01
Investigation	3.04	3.03	0.89	0.90	0.01	0.01
Equity	4.07	3.86	0.89	1.02	4.42**	0.21
Computer Usage	2.45	2.43	1.07	0.97	0.15	0.01
Young Adult Ethos	4.02	3.98	0.81	0.91	1.07	0.04
Attitudes						
Attitude to Subject	2.71	2.75	0.99	1.02	0.09	0.03
Attitude to Computers	2.02	2.03	0.81	0.82	0.02	0.01
Self Efficacy	2.76	2.61	0.90	0.91	2.62	0.16

N = 178 (Experimental) and 211 (Control)
** $p<0.01$

A possible explanation of why students in the CPS group perceived their learning environment as more equitable during class discussions could be that students were able to provide their own individual input to the conversation by responding to teacher-posed questions via CPS technology. Because each student in the experimental group received a CPS clicker that enabled him/her to be involved in each and every question during class discussions, perhaps this is why students felt that there was higher Equity relative to those students with teachers who had to call on individual students to answer questions.

4.4.2 Gender Differences in Learning Environment Perceptions and Attitudes

Although gender differences in learning environment perceptions and attitudes were not a focus of the research questions, some statistically significant results were revealed. The MANOVA results in Table 4.5, which are repeated in Table 4.7, show that there were gender differences for both Task Orientation and Attitude to Subject. Relative to males, females had higher (more positive) scores for Task Orientation (effect size = 0.21) and Attitude to Subject (effect size = 0.25). These effect sizes indicate gender differences that are small in magnitude. Relative to males, females liked science more and perceived that their classes were more task oriented.

Table 4.7 Average Item Mean, Average Item Standard Deviation and Gender Difference (ANOVA Result and Effect Size) for Each Learning Environment and Attitude Scale

	Average Item Mean		Average Item SD		Difference	
Scale	Male	Female	Male	Female	*F*	Effect Size
Learning Environment						
Involvement	3.04	3.04	0.84	0.83	0.01	0.00
Task Orientation	3.91	4.08	0.84	0.79	4.40**	0.21
Investigation	3.04	3.03	0.89	0.90	0.04	0.01
Equity	3.94	3.97	0.97	0.97	0.18	0.03
Computer Usage	2.50	2.39	1.06	0.97	1.38	0.11
Young Adult Ethos	3.93	4.00	0.83	0.89	0.74	0.08
Attitudes						
Attitude to Subject	2.60	2.85	0.97	1.03	6.08**	0.25
Attitude to Computers	1.99	2.06	0.87	0.76	0.78	0.08
Self Efficacy	2.62	2.74	0.87	0.93	2.19	0.13

N = 179 males and 210 females
**p<0.01

The 20-year research of King, Gurian and Stevens (2010) revealed different gender issues for males and females. Areas of difficulty for females included lower learning and engagement in science and technology, relational aggression in school and cyberspace, and low self-esteem (King et al., 2010). Therefore, the findings from the current study are promising in that females reported more positive attitudes towards science than did males.

4.4.3 Differential Effectiveness of CPS Technology Integration for Males and Females in Terms of Classroom Learning Environment and Attitudes

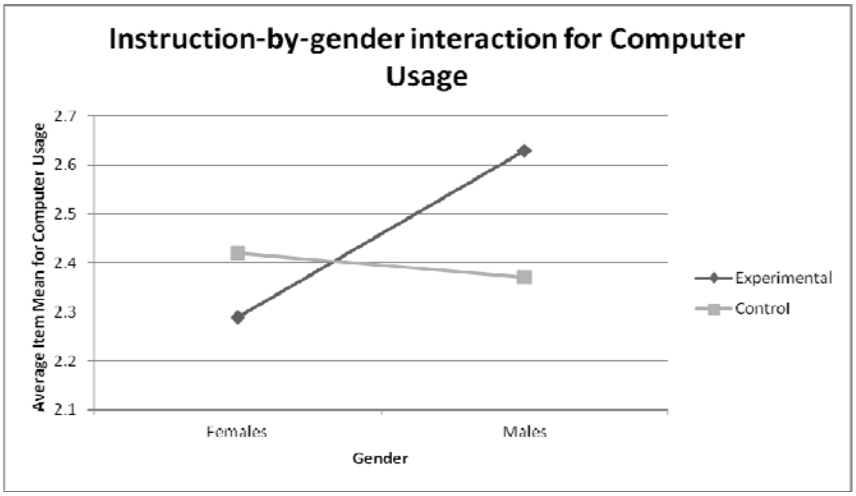
The differential effectiveness of CPS technology integration for males and females was the focus of the fourth research question:

> Research Question 4: Is Classroom Performance System (CPS) technology integration differentially effective for males and females in terms of:
>
> (a) classroom learning environment?
>
> (b) student attitudes toward science?

As noted previously in Section 4.4, a two-way MANOVA was used to explore differences between instructional groups and between genders for each learning environment and student attitudes scale. In particular, the interaction of the use/non-use of CPS technology integration with gender, as reported in Table 4.5, provided information about the differential effectiveness of CPS integration for males and females.

A statistically significant interaction ($p<0.01$) between instructional method and gender emerged only for one scale, namely, Computer Usage. Therefore, the independent interpretations of differences between instructional methods and between genders are valid for all scales except Computer Usage (Table 4.5). Figure 4.1 illustrates the interpretation of the significant instruction-by-gender interaction by providing a graph showing the average item mean for Computer Usage obtained by four groups, namely, females in the experimental group, males in the experimental group, females in the control group and males in the control group. As illustrated in Figure 4.1, for the experimental group, males perceived greater Computer Usage than females. However, for the control group, females perceived greater Computer Usage.

Figure 4.1 Instruction-by-gender Interaction for Computer Usage



King, Gurian and Stevens (2010) described the 'gender lens' and females' perceptions of lower levels of learning and engagement in science and technology. According to Heemskerk et al. (2009), females' learning improves when the technology used addresses their interests. Research conducted by Adebowale et al. (2010) suggests that females express more interest in technology than males when they can independently control the technology. Because males in the experimental group perceived higher Computer Usage than females, this could suggest that clickers have gender scripts similar to those in gaming systems that might lead to males perceiving higher Computer Usage.

4.5 Summary

This chapter reported the results for the current study's research questions, including validation of the instruments used, associations between classroom learning environment and student attitudes towards science, an evaluation of the effectiveness of Classroom Performance Systems (CPS) technology in terms of learning environment and attitudes, and the differential effectiveness of CPS for males and females. The instruments used were the TROFLEI and Attitude and Efficacy Questionnaire, which were responded to by 971 students for a pretest and 389 students for a posttest in a large high school in New York State.

Principal axis factor analysis with varimax rotation and Kaiser normalization was performed with data from the original 56-item, seven-scale version of the TROFLEI for four different data sets: both pretest and posttest administrations of both the actual and preferred versions of the instrument. The optimal factor solution occurred for a refined version with 46 items that all had a factor loading of at least 0.40 on the a priori scale and less than 0.40 on all other scales.

Table 4.1 reported the percentage of variance and eigenvalues for each scale of the TROFLEI. The total percentage of variance for the pretest actual version was 29.22, for the pretest preferred version was 29.71, for the posttest actual version was 30.47, for the posttest preferred version was 30.56. Eigenvalues for TROFLEI scales ranged from 1.64 to 12.72 for the pretest actual version, from 1.55 to 14.59 for the pretest preferred version, from 1.40 to 15.69 for the posttest actual version, and from 1.39 to 17.27 for the posttest preferred version.

When Cronbach's alpha coefficient was used to establish an index of internal consistency, reliability estimates for TROFLEI scales ranged from 0.82 to 0.92 for the pretest actual version, from 0.83 to 0.92 for the pretest preferred version, from 0.86 to 0.94 for the posttest actual version and from 0.86 to 0.94 for the posttest preferred version. These results suggest strong reliability for each of the six scales of the TROFLEI. Discriminant validity analyses supported the distinct nature of various TROFLEI scales. ANOVA results revealed that the actual form of nearly all TROFLEI scales could distinguish between students with different teachers.

Principal axis factor analysis with varimax rotation and Kaiser normalization also was used for data for the Attitude and Efficacy Questionnaire's three scales each containing eight items. No items needed to be removed for either the pretest and posttest administrations of the survey to the samples of 919 and 389 students, respectively. Table 4.2 reported the percentage of variance and eigenvalues for each scale of the Attitude and Efficacy Questionnaire. For the pretest, the percentage of variance varied from 14.77% to 34.88% for different scales, with the total variance accounted for being 18.10%. For the posttest, the percentage of variance varied from 11.54% to 40.99 % for different scales, with the total variance accounted for being 18.30%. The eigenvalues ranged from 3.54 to 8.37 for the pretest and from 2.77 to 9.83 for the posttest. The internal consistency reliability of the three attitude scales ranged from 0.89 to 0.95 for the pretest and from 0.91 to 0.96 for the posttest.

Associations between learning environment and student attitude scales were investigated using simple correlation and multiple regression analyses. For at least one unit of analysis, Involvement, Task Orientation, Investigation, Equity and Young Adult Ethos were significant independent predictors of student attitudes to science; Young Adult Ethos was a significant independent predictor of attitude to computers, and Involvement, Task Orientation, Investigation and Equity were significant independent predictors of student self efficacy. All relationships were positive, indicating a positive link between students' attitudes and aspects of the learning environment as in past research (Fraser, in press).

The effectiveness of inquiry instruction was also reported in this chapter based on the posttest administration of the surveys to 389 students in 57 classes. Of these, 20 classes were exposed to CPS technology integration, while the other 37 classes were exposed to classroom learning environments that did not have CPS technology integration. The data set consisted of 179 male and 210 female students. A two-way MANOVA was used to investigate differences in student perceptions of the classroom learning environment and attitudes between the experimental and control groups (CPS versus non-CPS) as well as between genders. Because the MANOVA showed significant differences overall using Wilks' lambda criterion, the univariate ANOVA was interpreted for each individual environment and attitude scale (Table 4.5). Differential effectiveness was identified through any significant instructional method-by-gender interactions.

Although differences between users and non-users of CPS generally were small and statistically nonsignificant, a statistically significant difference of 0.21 ($p<0.01$) standard deviations emerged for Equity. Students in the CPS group perceived their learning environments as more equitable.

Significant but small gender differences of around one-fifth of a standard deviation were found for Task Orientation ($p<0.01$) and Attitude to Subject ($p<0.01$). Relative to males, females liked science more and perceived that their classes were more task oriented. As well, a significant but small instruction-by-gender interaction emerged for one scale. For the CPS group, males perceived greater Computer Usage than females. However, for the control group, females perceived greater Computer Usage.

Further discussion of these results appears in the following chapter. Implications for classroom practices and limitations of the current study also are discussed.

Chapter 5
Discussion

5.1 Introduction

This study was concerned primarily with students' perceptions of their learning environment and attitudes during the integration of Classroom Performance System (CPS) technology into high-school science classrooms. Other research foci were: the validation of questionnaire scales assessing classroom environment and student attitudes; associations between student attitudes and the classroom environment; and the differential effectiveness of CPS usage for male and female students.

The learning environment questionnaire was administered in both its actual and preferred forms. Both learning environment and attitude scales were administered to a sample of 971 students as a pretest and to 389 as a posttest. All of these grade 9–12 students were studying science at a high school in New York State. The attrition between pretest and posttest administrations was attributable mainly to a large number of student absences during the posttest administration of questionnaires.

This chapter provides a summary of findings as reported in Chapter 4 (Section 5.2), discusses its educational significance and implications (Section 5.3), identifies some limitations (Section 5.4), and provides recommendations for future research (Section 5.5).

5.2 Summary of Results

The following subsections provide a summary of the findings related to each research question for the current study.

5.2.1 Results for Research Question 1

Research Question 1: *Is a modified version of the* Technology-Rich Outcomes-Focused Learning Environments Inventory (TROFLEI) *and the* Attitude and

Efficacy Questionnaire *valid when used with a sample from a large school district in New York State?*

In order to assess the classroom learning environment, both the actual and preferred versions of a modified form of the Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) were used (Appendix A). The TROFLEI was modified because only seven of its original scales were highly relevant to the research questions and for the purpose of reducing the amount of time needed for students to answer the survey. The Attitude and Efficacy Questionnaire was used without alteration to measure student attitudes. Both the TROFLEI and Attitude and Efficacy Questionnaire were administered as both pretests and posttest.

The data analyses in this section are reported separately for the pretest sample of 971 students and for the posttest sample of 389 students. As well, validity results on the TROFLEI are reported separately for actual and preferred versions.

Principal axis factor analysis with varimax rotation and Kaiser normalization was used to check the structure of each questionnaire. The criteria for retaining any item were that it must have a loading of at least 0.40 on its a priori scale and less than 0.40 on all other scales. Successive factor analyses were performed for the four TROFLEI data sets (actual and preferred versions of both the pretest and posttest) until the optimal factor solution was reached. Table 4.1 indicated that the optimal factor solution for each of the four data sets was obtained by retaining 46 of the original 56 TROFLEI items. The whole Differentiation scale, as well as one item each from the Involvement and Computer Usage scales, were removed to improve internal consistency reliability and factorial validity. The six scales retained were Involvement, Task Orientation, Investigation, Equity, Computer Usage and Young Adult Ethos. For the different TROFLEI data sets, the percentage of variance accounted for by different scales ranged from 1.73% to 35.99% and the eigenvalues for different scales ranged from 1.39 to 17.27. When the Cronbach alpha reliability coefficient was used as an index of scale internal consistency, strong internal consistency reliability was found for the TROFLEI (with scale reliability estimates ranging from 0.82 to 0.94 for the different databases).

For the 24-item Attitude and Efficacy Questionnaire (Appendix A) assessing Attitude to Subject, Attitude to Computers and Self Efficacy, factor analysis was conducted separately for pretest and posttest data. As shown in Table 4.2, because all items had factor loadings of at least 0.40 on their a priori scales and less than 0.40 on the other two scales (for both pretest and posttest data), all items were retained. The percentage of variance for different scales ranged from 11.54% to 40.99% for both data sets and scale eigenvalues ranged from 2.77 to 9.83. The Cronbach alpha reliability coefficient indicated strong values ranging from 0.89 to 0.96 for the two data sets.

To ensure that each of the individual scales of modified versions of the TROFLEI and the Attitude and Efficacy Questionnaire measures a unique dimension, discriminant validity was examined. The mean correlation of each scale with the other scales was used as a convenient index of discriminant validity. Table 4.3 indicates that most scales were fairly unique in the dimension that each assessed. These results, with support from the factor analyses, suggest that each scale in each instrument measures a relatively unique dimension.

To determine the degree to which the actual version of each TROFLEI scale was able to differentiate between the perceptions of students with different teachers, a one-way ANOVA was computed for each TROFLEI scale. The ANOVA results reported in Table 4.3 show that nearly all TROFLEI scales differentiated significantly between students with different teachers for both pretest and posttest data. That is, students with the same teacher perceived the environment in a relatively similar manner, while the mean perceptions of the students varied between students with different teachers. The proportion of variance accounted for by class membership was calculated using the eta^2 statistic.

Overall, the results found in the current study provide strong support for the validity of both the TROFLEI and Attitude and Efficacy Questionnaire when used with high-school science students in New York State. Therefore, the results replicate validity findings reported for this attitude questionnaire in Australia (Aldridge & Fraser, 2008) and New Zealand (Koul et al., 2011) and in numerous studies that have used questionnaires that encompass many of the TROFLEI scales included in the current study (Aldridge & Fraser, 2000, 2008; Dorman, 2003; Fraser, in press; Koul et al., 2011).

5.2.2 Results for Research Question 2

Research Question 2: *Are there associations between classroom learning environment and student attitudes toward science?*

Scale scores on the refined versions of the TROFLEI and Attitude and Efficacy Questionnaire were used in exploring associations between students' perceptions of the learning environment and student attitudes toward science. Simple correlation and multiple regression analyses were used to examine the relationships between student perceptions of the classroom environment and the student attitudes. Simple correlations were used to describe the bivariate relationship between each student attitude and each environment scale. Multiple regression analysis was carried out to examine the joint influence of the whole set of correlated environment scales on each attitude outcome, as well as to identify which individual environment scales contributed most to the variance in students' attitudes when all other environment scales were mutually controlled. All analyses were performed separately for pretest data (971 students) and posttest data (389 students). As indicated in Table 4.4, nearly all of the six scales of the TROFLEI correlated positively and significantly with each of the three student attitude scales for both the pretest and posttest data.

The multiple correlation between the set of six TROFLEI scales and each of the three Attitude and Efficacy Questionnaire scales was statistically significant, indicating that there were associations between learning environment scales (Involvement, Task Orientation, Investigation, Equity, Computer Usage and Young Adult Ethos) and the three attitude scales (Attitude to Subject, Attitude to Computers and Student Self Efficacy).

Standardized regression weights were employed in determining the contribution of each TROFLEI scale to the variance in each attitude scale when the other learning environment scales were mutually controlled (Table 4.4). Four of the six TROFLEI scales for the pretest data uniquely accounted for a significant amount of variance in students' Attitude to Subject (Involvement, Task Orientation, Investigation and Young Adult Ethos). Only two of the six TROFLEI scales for the posttest data uniquely accounted for a significant amount of variance in Attitude to Subject (Investigation and Equity). The standardized regression weights indicated that only the Young Adult Ethos scale accounted for a significant amount of variance in student Attitude to Computers for both pretest and posttest data. For Self Efficacy, two of the six TROFLEI scales accounted for a significant amount of variance for the pretest (Involvement and Task Orientation) and four of the six TROFLEI scales accounted for a significant amount of variance for the posttest (Involvement, Task Orientation, Investigation and Equity).

Because all statistically significant attitude-environment relationships were positive, this suggests a positive link between students' Attitude to Subject, Attitude to Computers and Student Self Efficacy and the aspects of outcomes-focused learning environments assessed by the TROFLEI. Therefore, this research study replicates a large volume of past research around the world that has consistently revealed positive associations between students' attitudes and classroom environment dimensions (Fraser, in press; Goh, Young & Fraser, 1995; Haertel, Walberg & Haertel, 1981; McRobbie & Fraser, 1993).

5.2.3 Results for Research Questions 3 and 4

Research Question 3: *Is Classroom Performance System (CPS) technology integration effective in terms of:*

- *(a) classroom environment?*
- *(b) student attitudes toward science?*

Research Question 4: *Is Classroom Performance System (CPS) technology integration differentially effective for males and females in terms of:*

- *(c) classroom learning environment?*
- *(d) student attitudes toward science?*

These two research questions were investigated simultaneously based on data from the posttest administration of the surveys to 389 students in 57 classes. Of these, 20 classes utilized the CPS integrated instruction, while the other 37 classes did not use the CPS integrated instruction. This data set consisted of 179 male and 210 female students. A two-way MANOVA was used to investigate differences in student perceptions of the classroom learning environment and attitudes between the experimental and control groups (CPS versus non-CPS), as well as between genders. Differential effectiveness was identified through the presence of any significant instructional method-by-gender interactions. Because the MANOVA showed significant differences ($p<0.05$) overall using Wilks' lambda criterion, the univariate ANOVA was interpreted for each individual environment and attitude sub-scale (Table 4.5).

In the two-way MANOVA, the dependent variables consisted of the TROFLEI learning environment scales and the attitude scales from the Attitude and Efficacy Questionnaire. The two independent variables were the instructional method (CPS vs. non-CPS). In addition to using MANOVA to determine statistical significance, effect sizes (Cohen, 1988) were used to indicate the magnitude of effects. The effect size for instructional differences was calculated by dividing the difference between the means of the two instructional groups by the pooled standard deviation. It expresses the between-group difference in means in standard deviation units.

Although differences between users and non-users of CPS generally were small and statistically nonsignificant, a statistically significant difference of 0.21 ($p<0.01$) standard deviations emerged for Equity. Students in the CPS group perceived their learning environments as somewhat more equitable.

Statistically significant but small gender differences of around one-fifth of a standard deviation were found for Task Orientation and Attitude to Subject. Relative to males, females liked science more and perceived that their classes were more task oriented. As well, a significant but small instruction-by-gender interaction emerged for one scale, Computer Usage. For the CPS group, males perceived greater Computer Usage than females. However, for the control group, females perceived greater Computer Usage (Figure 4.1).

5.3 Significance and Implications

This research has contributed to the field of learning environments. It is significant that the current study represents the first evaluation of the use of CPS that employed learning environment dimensions as criteria of effectiveness. Clearly more information about the effectiveness of CPS technology would be useful for guiding purchasing decisions.

The instruments used in the current study were shown to be reliable and valid for a sample of high-school science students (Section 4.2). Therefore, the Technology-Rich Outcomes-Focused Learning Environments Inventory (TROFLEI) and Attitude and Efficacy Questionnaire can be used with confidence in the future by researchers and teachers to provide an economical assessment of student perceptions of the classroom learning environment and their attitudes toward science.

The results of this study support previous studies (Aldridge & Fraser, 2008; Koul et al., 2011) in that the six aspects of the learning environment selected for this study (Involvement, Task Orientation, Investigation, Equity, Computer Usage and Young Adult Ethos), as assessed by the TROFLEI scales, correlated positively with student attitudes. This positive association has contributed to the evidence that the learning environment is positively linked with student attitudes. The results of this study support the importance of the field of learning environments for improving student attitudes.

The finding of empirical links between positive attitudes and Involvement, Task Orientation, Investigation, Equity, Computer Usage and Young Adult Ethos reveals the importance of teachers establishing a classroom learning environment that has all six of these features. Teachers should make sure that students feel involved and task oriented. Teachers should foster an environment where students are all equally engaged in investigations. Students should have the opportunity to participate equally and receive the same amount of guidance from the teacher. Instruction should be supported by computer usage. Teachers should also help students to build their confidence in the subject as well.

The results of this study suggest that Classroom Performance System (CPS) technology might not be as effective as educators and policymakers would hope. Numerous previous studies have failed to identify positive outcomes associated with CPS-like technology integration; all of these researchers speculated that pedagogy was the missing link to success (Draper, 1998; Draper & Brown, 2004; Judson & Sawada, 2002). Teachers can use the lack of significant findings for effectiveness of

CPS technology integration as a cue to use technology in order to enhance different pedagogical strategies and not depend on CPS to improve the learning environment independently of changes to instructional strategies.

In the current study, the experimental group did perceive significantly greater Equity than the control group. Students who used CPS clickers felt that teachers treated students more equally in those classrooms. However, the difference was small (around one-fifth of a standard deviation).

This study also is significant because the differential effectiveness of CPS usage for males and females was investigated. Males perceived greater Computer Usage in CPS classes, but females perceived greater Computer Use in non-CPS classes. This possibly suggests that CPS clickers might contain gender scripts that favor male students.

Educators and policy makers need to focus on providing appropriate professional development in implementing technologies such as CPS as opposed to simply purchasing additional equipment. Encouraging or requiring the use of technology in the classroom without adequate training could waste valuable time and funding resources that could be better used elsewhere.

5.4 Limitations

Multiple precautions were in place to reduce the effects of potential limitations in this study, but some were unavoidable. Because it is impossible to accommodate every contributing factor in a single study, there were numerous limitations in this research study.

The survey assessing student perceptions of their classroom learning environment and attitudes towards science was administered to students on two separate occasions (a pretest before the units were taught and a posttest at the culmination of the units) to increase the comprehensiveness of the data available for analysis and in an effort to compare pretest and postest data. However, for reasons described below, there was a large degree of attrition between pretest and posttest, which greatly reduced the number of matched pretest-posttest responses and constituted a limitation. Although the survey could be administered using any computer with an internet connection, there was limited availability of computers in the building where the survey responses were collected. Therefore, surveys were administered using a mobile laptop cart that is shared by the entire science department. So, if students were absent from class on the days when the survey was administered, they did not submit responses on that day. As a result, many students did not submit matched pretest and posttest survey responses. There were 971 students who submitted pretest surveys while only 389 students submitted posttest surveys. Therefore, it was not meaningful to compare pretest and posttest data with such a small sample of matched responses.

Nevertheless, in order to establish the validity and reliability of the instruments, both the larger pretest sample and smaller posttest sample were used to maximize the comprehensiveness and usefulness of the validity analyses. However, it would be beneficial in future studies to avoid the attrition between pretest and posttest experienced in this research study in order to provide information about the changes in responses during the experimental period.

For convenience, the data in the current study were collected from a single school in a building where the researcher works. Although the sample was from only one school, the enrolment in earth science and biology courses is very large and heterogeneous and is typical of many schools in New York State. However, generalizations should be made cautiously as the results are from students for a single school. A larger sample encompassing a set of schools might have provided a greater level of confidence and reduced individual idiosyncrasies that could have existed for the group of students used in this study. The school used was the one in which the researcher taught; this allowed the researcher to carry out research with her students and to assist the other science teachers who conducted the study. Although the researcher working in the building where the study was conducted did not seem to have any effect on the outcomes of the study, this information should be noted as a possible limitation.

In this study, teachers were given the authority to decide their methods of implementation of the CPS technology. Because the extent to which and the methods used in implementing the technology were left up to the individual teacher's discretion, generalizations about the effectiveness of the technology should be made with caution.

Another limitation was the absence of qualitative data in the current study. According to Tobin and Fraser (1998), learning environment research can be enhanced by using multiple research methods to provide both qualitative and quantitative data. Research that uses a variety of modes of data collection can lead to complementary insights and help to identify problems and probable solutions in the field of learning environments. The complexity of classroom learning environments has created the need for multiple modes of data collection, both quantitative and qualitative, to obtain credible and authentic outcomes (Tobin & Fraser, 1998). Aldridge, Fraser and Huang (1999) used both quantitative and qualitative data in exploring students' perceptions, identifying factors that influence the learning environment, making meaningful interpretations and providing insights that could not otherwise be revealed with just quantitative data. Because qualitative data collection might have provided further insight into the statistically significant findings from the quantitative analyses conducted in the current study, its absence constitutes a potential limitation.

The absence of an achievement measure is another limitation as the improvement of student achievement is a goal of most initiatives in education. Clearly, the inclusion of an achievement measure could have provided further insights into the effectiveness of using CPS.

5.5 Recommendations for Further Research

Despite the potential limitations identified above, this study still has provided some useful insights about the use of CPS and leads to some desirable directions for future research. For example, additional studies of instructional methods, using a combination of both quantitative and qualitative methods, might enhance understanding of implementing Classroom Performance System (CPS) technology.

Although attrition in this study made it not meaningful to compare the small sample of matched pretest and posttest data, future research should focus on making this comparison possible. In order to better accomplish this goal, surveys should be administered in school buildings where the availability of computers for questionnaire administration is not so limited that it hinders data collection from students who are absent from class on the days scheduled for taking of the surveys. If the availability of computers for questionnaire administration was an issue, perhaps it might have been useful to have a scheduled make-up session for questionnaire administration to students who were absent during the original administration date.

In order to allow researchers to identify differences between instructional groups with greater confidence in future research, larger, more-diverse, and more-representative samples would be highly desirable.

Because there were few statistically significant findings regarding the effectiveness of CPS technology in the current study, it is suggested that a productive focus for future research could be the pedagogy that is assisted by CPS technology. That is, research could focus on how to use CPS technology to make improvements in pedagogy.

As noted in Section 5.4, the absence of an achievement measure was a limitation. Therefore, in future research, it would be desirable to include achievement as one of the criteria of instructional effectiveness when evaluating CPS usage.

The current study included exploration of the differential effectiveness of using CPS for students of different genders. In future research, it might be useful also to investigate the differential effectiveness of CPS for students varying in other background variables such as ethnicity or socioeconomic status.

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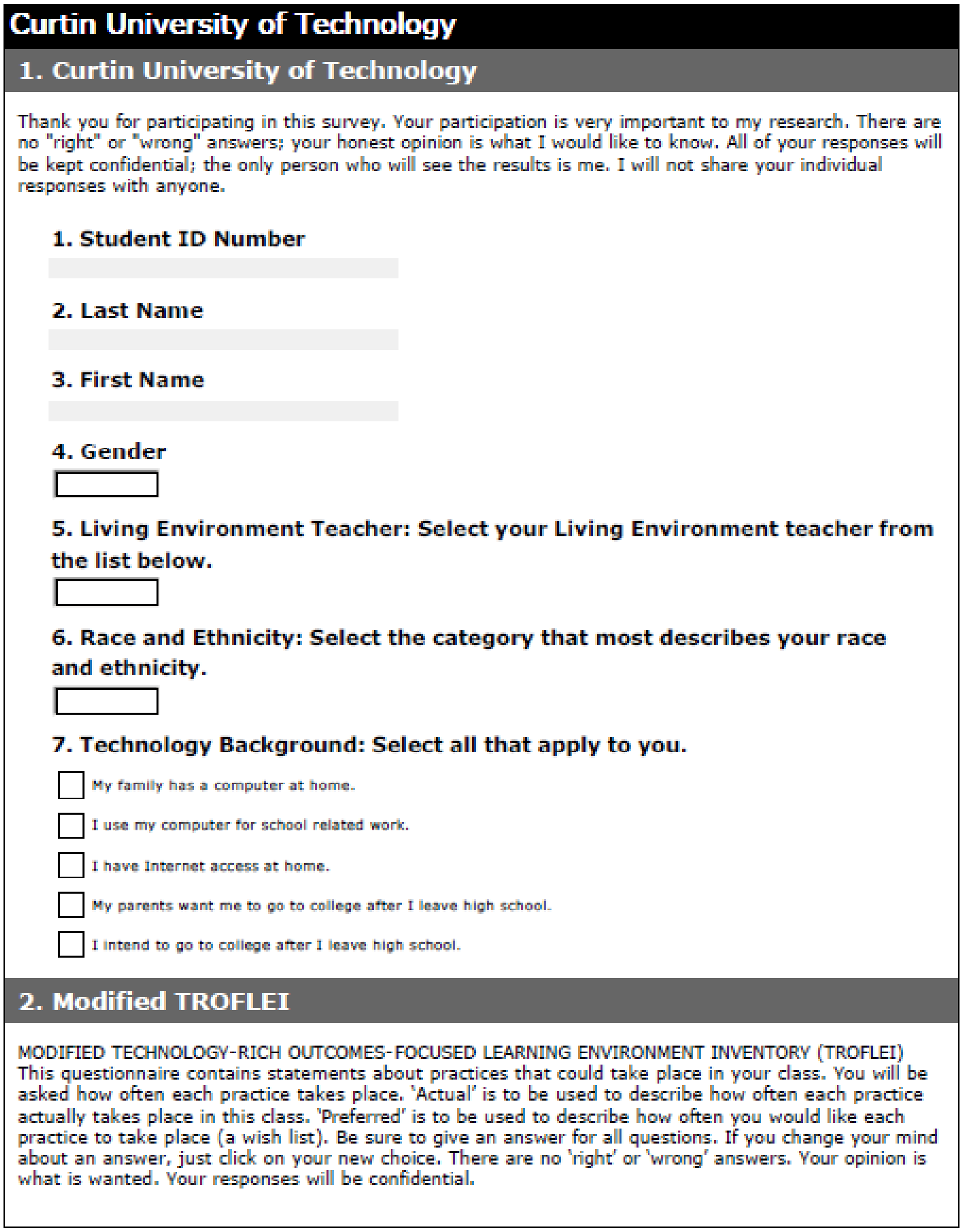
Appendix

This Appendix contains the survey used in this study.

[1]

In this questionnaire, items 1-56 in Section 2 (Modified TROFLEI) are based on the Technology-Rich Outcomes-Focused Learning Environments Inventory (TROFLEI) (Aldridge & Fraser, 2008) as described in Section 2.2.2.10 and items 1-24 in Section 3 (Attitude Measures) are based on the Attitudes and Efficacy Questionnaire (Aldridge & Fraser, 2008) described in Section 2.3.2. These questionnaire items were used in the current study and included in this thesis with the authors' permission.

Appendix A: Survey (Includes a modified version of TROFLEI and Attitude and Efficacy Questionnaire)



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1. Curtin University of Technology

Thank you for participating in this survey. Your participation is very important to my research. There are no "right" or "wrong" answers; your honest opinion is what I would like to know. All of your responses will be kept confidential; the only person who will see the results is me. I will not share your individual responses with anyone.

1. Student ID Number

2. Last Name

3. First Name

4. Gender

5. Living Environment Teacher: Select your Living Environment teacher from the list below.

6. Race and Ethnicity: Select the category that most describes your race and ethnicity.

7. Technology Background: Select all that apply to you.

- [ ] My family has a computer at home.
- [ ] I use my computer for school related work.
- [ ] I have Internet access at home.
- [ ] My parents want me to go to college after I leave high school.
- [ ] I intend to go to college after I leave high school.

2. Modified TROFLEI

MODIFIED TECHNOLOGY-RICH OUTCOMES-FOCUSED LEARNING ENVIRONMENT INVENTORY (TROFLEI)
This questionnaire contains statements about practices that could take place in your class. You will be asked how often each practice takes place. 'Actual' is to be used to describe how often each practice actually takes place in this class. 'Preferred' is to be used to describe how often you would like each practice to take place (a wish list). Be sure to give an answer for all questions. If you change your mind about an answer, just click on your new choice. There are no 'right' or 'wrong' answers. Your opinion is what is wanted. Your responses will be confidential.

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1. I discuss ideas in class.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

2. I give my opinions during class discussions.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

3. The teacher asks me questions.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

4. My ideas and suggestions are used during classroom discussions.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

5. I ask the teacher questions.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

6. I explain my idea to other students.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

7. Students discuss with me how to go about solving problems.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

8. I am asked to explain how I solve problems.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

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9. Getting a certain amount of work done is important to me.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

10. I do as much as I set out to do.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

11. I know the goals for this class.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

12. I am ready to start this class on time.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

13. I know what I am trying to accomplish in this class.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

14. I pay attention during this class.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

15. I try to understand the work in this class.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

16. I know how much work I have to do.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

17. I carry out investigations to test my ideas.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

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18. I am asked to think about the evidence for statements.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

19. I carry out investigations to answer questions coming from discussions.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

20. I explain the meaning of statements, diagrams and graphs.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

21. I carry out investigations to answer questions that puzzle me.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

22. I carry out investigations to answer the teacher's questions.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

23. I find out answers to questions by doing investigations.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

24. I solve problems by using information obtained from my own investigations.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

25. The teacher gives as much attention to my questions as to other students' questions.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

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26. I get the same amount of help from the teacher as do other students.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

27. I have the same amount of say in this class as other students.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

28. I am treated the same as other students in this class.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

29. I receive the same encouragement from the teacher as other students do.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

30. I get the same opportunity to contribute to class discussions as other students.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

31. My work receives as much praise as other students' work.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

32. I get the same opportunity to answer questions as other students.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

33. I work at my own speed.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

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34. Students who work faster than me move on to the next topic.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

35. I am given a choice of topics.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

36. I am set tasks that are different from other students' tasks.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

37. I am given work that suits my ability.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

38. I use different materials from those used by other students.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

39. I use different assessment methods from other students.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

40. I do work that is different from other students' work.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

41. I use the computer to type my assignments.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

42. I use the computer to email assignments to my teacher.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

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43. I use the computer to ask the teacher questions.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

44. I use the computer to find out information about the course.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

45. I use the computer to read lesson notes prepared by the teacher.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

46. I use the computer to find out information about how my work will be assessed.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

47. I use the computer to take part in online discussions with other students.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

48. I use the computer to obtain information from the Internet.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

49. I am treated like a young adult.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

50. I am given responsibility.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	○	○	○	○	○
Preferred	○	○	○	○	○

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51. I am expected to think for myself.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	◯	◯	◯	◯	◯
Preferred	◯	◯	◯	◯	◯

52. I am dealt with as a grown up.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	◯	◯	◯	◯	◯
Preferred	◯	◯	◯	◯	◯

53. I am regarded as reliable.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	◯	◯	◯	◯	◯
Preferred	◯	◯	◯	◯	◯

54. I am considered mature.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	◯	◯	◯	◯	◯
Preferred	◯	◯	◯	◯	◯

55. I am given the opportunity to be independent.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	◯	◯	◯	◯	◯
Preferred	◯	◯	◯	◯	◯

56. I am encouraged to take control of my own learning.

	Almost Never	Seldom	Some times	Often	Almost Always
Actual	◯	◯	◯	◯	◯
Preferred	◯	◯	◯	◯	◯

3. Attitude Measures

This test contains a number of statements about science. You will be asked what you yourself think about these statements. There are no 'right' or 'wrong' answers. Your opinion is what is wanted.

1. I look forward to lessons in this subject.

◯ STRONGLY AGREE ◯ AGREE ◯ NOT SURE ◯ DISAGREE ◯ STRONGLY DISAGREE

2. Lessons in this subject are fun.

◯ STRONGLY AGREE ◯ AGREE ◯ NOT SURE ◯ DISAGREE ◯ STRONGLY DISAGREE

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3. I like lessons in this subject.

○ STRONGLY AGREE ○ AGREE ○ NOT SURE ○ DISAGREE ○ STRONGLY DISAGREE

4. Lessons in this subject interest me.

○ STRONGLY AGREE ○ AGREE ○ NOT SURE ○ DISAGREE ○ STRONGLY DISAGREE

5. This subject is one of the most interesting school subjects.

○ STRONGLY AGREE ○ AGREE ○ NOT SURE ○ DISAGREE ○ STRONGLY DISAGREE

6. I enjoy lessons in this subject.

○ STRONGLY AGREE ○ AGREE ○ NOT SURE ○ DISAGREE ○ STRONGLY DISAGREE

7. Lessons in this subject are a good use of my time.

○ STRONGLY AGREE ○ AGREE ○ NOT SURE ○ DISAGREE ○ STRONGLY DISAGREE

8. These lessons make me interested in this subject.

○ STRONGLY AGREE ○ AGREE ○ NOT SURE ○ DISAGREE ○ STRONGLY DISAGREE

9. I'm good with computers.

○ STRONGLY AGREE ○ AGREE ○ NOT SURE ○ DISAGREE ○ STRONGLY DISAGREE

10. I like working with computers.

○ STRONGLY AGREE ○ AGREE ○ NOT SURE ○ DISAGREE ○ STRONGLY DISAGREE

11. Working with computers inspires me.

○ STRONGLY AGREE ○ AGREE ○ NOT SURE ○ DISAGREE ○ STRONGLY DISAGREE

12. I am comfortable trying new software on the computer.

○ STRONGLY AGREE ○ AGREE ○ NOT SURE ○ DISAGREE ○ STRONGLY DISAGREE

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13. Working with computers is motivating.

◯ STRONGLY AGREE ◯ AGREE ◯ NOT SURE ◯ DISAGREE ◯ STRONGLY DISAGREE

14. Working on a computer makes my work more enjoyable.

◯ STRONGLY AGREE ◯ AGREE ◯ NOT SURE ◯ DISAGREE ◯ STRONGLY DISAGREE

15. I do as much work as I can using a computer.

◯ STRONGLY AGREE ◯ AGREE ◯ NOT SURE ◯ DISAGREE ◯ STRONGLY DISAGREE

16. I feel comfortable using a computer.

◯ STRONGLY AGREE ◯ AGREE ◯ NOT SURE ◯ DISAGREE ◯ STRONGLY DISAGREE

17. I find it easy to get good grades in this subject.

◯ STRONGLY AGREE ◯ AGREE ◯ NOT SURE ◯ DISAGREE ◯ STRONGLY DISAGREE

18. I am good at this subject.

◯ STRONGLY AGREE ◯ AGREE ◯ NOT SURE ◯ DISAGREE ◯ STRONGLY DISAGREE

19. My friends ask me for help in this subject.

◯ STRONGLY AGREE ◯ AGREE ◯ NOT SURE ◯ DISAGREE ◯ STRONGLY DISAGREE

20. I find this subject easy.

◯ STRONGLY AGREE ◯ AGREE ◯ NOT SURE ◯ DISAGREE ◯ STRONGLY DISAGREE

21. I outdo most of my classmates in this subject.

◯ STRONGLY AGREE ◯ AGREE ◯ NOT SURE ◯ DISAGREE ◯ STRONGLY DISAGREE

22. I have confidence that I can pass this subject.

◯ STRONGLY AGREE ◯ AGREE ◯ NOT SURE ◯ DISAGREE ◯ STRONGLY DISAGREE

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23. I am an intelligent student.

◯ STRONGLY AGREE ◯ AGREE ◯ NOT SURE ◯ DISAGREE ◯ STRONGLY DISAGREE

24. I help my friends with their homework in this subject.

◯ STRONGLY AGREE ◯ AGREE ◯ NOT SURE ◯ DISAGREE ◯ STRONGLY DISAGREE