Science and Mathematics Education Centre

EVALUATION OF ANTHROPOMETRY ACTIVITIES FOR HIGH SCHOOL SCIENCE: STUDENT OUTCOMES AND CLASSROOM ENVIRONMENT

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ABSTRACT

The study involved the evaluation of anthropometric activities for high school science. The activities actively engaged students in the process of gathering, processing and analyzing data derived from human body measurements, with students using their prior knowledge acquired in science, mathematics and computer classes to interpret this information.

Quantitative (survey) and qualitative (interview) methods were used to provide answers to the research questions. The quantitative portion of the study involved students' achievement, students' attitudes to science and students' perceptions of the classroom learning environment. A pretest/posttest design was used with achievement outcomes; however, only a single assessment of student attitudes and classroom environment was made.

The sample size used to gather data on students' attitudes to science and students' perceptions of the learning environment was 726 students. Five hundred and ninety-eight (598) students took the biology test. However, analyses were restricted to the subsample of 158 students who had experienced the anthropometric laboratory activity. Twenty-four students (24) were interviewed for the qualitative part of the study. Data generated from the interviews were used to complement information provided in the surveys.

The main purpose of this research was to evaluate these student-centered activities in terms of students' achievement, students' attitudes and students' perceptions of the science classroom environment. Other aims included: to validate generally-applicable measures of classroom learning environments and students' attitudes to science; to investigate gender differences in students' achievement, attitudes and perceptions of classroom environment; and to investigate associations between the classroom learning environment and the student outcomes of performance and attitudes.

Some of the important findings of this study included:

1. In reference to the survey instruments, the item analyses supported the internal consistency reliability and ability to differentiate between classrooms of the learning environment questionnaire and the analyses of attitude data supported the factorial validity, internal consistency reliability and discriminant validity of the attitude questionnaire.

2. Substantial differences between the pretest and posttest scores for the achievement measures in Biology and anthropometric activities were found. These findings were supported by statistically significant *t*-test scores and effect sizes.

3. There was a positive influence of using anthropometric activities on both students' attitudes and their perceptions of the classroom learning environment. The findings

based on qualitative information (interviews, which involved twenty-four students) were consistent with patterns emerging from our quantitative information (surveys, which involved 760 students) and they supported the effectiveness of the anthropometric activities.

4. The analysis of gender differences in students' achievement, attitudes and perceptions of classroom environment revealed that boys have more positive attitudes to science than girls do and is in agreement with past studies. However, females' students demonstrated more favorable perceptions of the learning environment than males, primarily with Student Cohesiveness and Rule Clarity.

5. The association between student attitudes and their perception of the learning environment indicated that students' attitudes to science are most likely to be positive in laboratory classes where student perceive a strong integration between the concepts and principles covered in theory classes and in laboratory classes. These findings are consistent with results in other countries.

6. The association between achievement and student perceptions of their learning environment, suggest that integration of theoretical concepts with laboratory activities (Integration), a cohesive student group (Student Cohesiveness) and using appropriate laboratory materials and equipment (Material Environment) are likely to lead to student achievement. This finding replicates the results of previous studies.

7. I found stronger outcome-environment associations for attitudes than for achievement. This finding is consistent with results from past research.

The contributions and significance of this study can be summarized as follows:

1. One of the key components of this study was the development and implementation of the innovative anthropometric laboratory activity, which was especially designed for this research.

2. Another contribution of this study is to the field of integrated curriculum instruction. While most instructional curricular activities are subject specific, this study is interdisciplinary in nature because it effectively links concepts and skills from science, mathematics, statistics, and technology (graphing calculators and computers).

3. A unique feature of this research is that it had an evaluation component involving student performance, student attitudes, and the nature of the classroom learning environment. Therefore, the study contributes to the field of learning environment research by adding another study to the limited research that has employed the classroom environment as a criterion of effectiveness in evaluating educational innovations.

The study has the potential to help other science teachers to apply these ideas in their classrooms.

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Chapter 1

INTRODUCTION AND OVERVIEW

The most important purpose of education is to prepare students to lead successful, fulfilling and responsible lives within our society. Science education — meaning education in science, mathematics, and technology — should provide students with process and thinking skills that are significant both at the individual and society levels.

Integrating concepts in mathematics, science and technology has been a major national educational goal. Former President George P. Bush stated that one of the goals in the America 2000 education strategy was that U.S. students would be the first in the world in science and mathematics achievement (Bush, 1990). Most curricular reform in science and mathematics share the idea that the integration of science and mathematics teaching and learning is an excellent way of improving achievement and attitudes within both disciplines. Berlin (1991) stated that there are multiple synonyms for the word integration, such as connection, cooperation, cross-disciplinary, interactions and interdisciplinary, with each referring to different degrees of integration. In some cases, mathematics is taught as a prerequisite tool for science and, in other cases, mathematics can be applied to science problems and also science and mathematics can be taught in concert in a real-world problem-solving context.

My study involved the use of an academic activity that integrates concepts in science, mathematics and technology. Integration was used to help students to visualize the interdependence of these subject matters. The innovative idea proposed in my study involved the evaluation of a hands-on science activity in terms of students' performance, their attitudes to science, and their perceptions of the classroom environment.

This chapter provides the background from which the present study was formulated and implemented, using five sections. Section 1.1 describes the conceptual framework; Section 1.2 reports the context of the study; Section 1.3 delineates the aims of the study; Section 1.4 provides an overview of the study; and Section 1.5 clarifies the contributions and significance of the study.

1.1 Conceptual Framework

My study is grounded in and contributes to the field of learning environments. Two of the first formal studies in the field of learning environment go back over six decades to Lewin's human behavior model proposed in 1936 and Murray's (1938) needs-press model. Lewin (1936) was probably the first to point out that human behavior is a function of the interaction between the individual person and his/her environment. Murray (1938) was the first to use Lewin's approach to propose a needs-press model, which refers to the interaction between person and environment.

Since the pioneering work of Lewin (1936) and Murray (1938), research in the field of learning environment has blossomed over the past 60 years with several major accomplishments such as: the development of numerous valid and widely-applicable learning environment instruments (Fraser, 1998b); the use of multiple methodologies in the same research study (Tobin & Fraser, 1998); and the establishment of associations between students' perceptions of their learning environment and students' outcomes such as attitudes and performance (Fraser, 1994).

The development, adaptation and validation of several learning environment instruments were important contributions to the field of learning environment because these instruments assess perceptions of classroom environment. Most of the historical and contemporary survey instruments were grounded in Moos' (1974) scheme for classifying human environments. Moos described three types of dimensions: Relationship Dimensions (which identify the nature and intensity of personal relationships); Personal Development Dimensions (which assess basic directions of personal growth and self-enhancement); and System Maintenance and System Change Dimensions (which describe if the environment has order and clear expectations, maintains control and is responsive to change). Later on, by applying the concept of person-environment fit, actual and preferred forms of the survey instruments were developed.

The pioneering work in the development of the first historically-important learning environment survey instruments can be attributed to Walberg's Learning Environment Inventory (LEI) (Walberg & Anderson, 1968) and Moos' Classroom Environment Scales (CES) (Moos 1979; Moos & Trickett 1987). The contributions made by Walberg and Moos served as fertile soil for the germination and development of contemporary survey instruments such as the 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 Classroom (WIHIC). In my study, the Science Laboratory Environment Inventory (SLEI) was used to measure student perceptions of the science classroom. Fraser (1998b) provides an excellent overview of the historical and contemporary learning environment survey instruments.

The use of mixed methods in the same research reflects a more recent trend in learning environment studies. In my study, both quantitative and qualitative methods were used to answer the research questions. The quantitative approach usually refers to variables and the relationships between them. Samples are typically larger than in qualitative studies, and generalization through sampling is usually important. The qualitative approach deals more with cases, it is sensitive to context and process, and it aims for in-depth and holistic understanding. Samples are usually small.

Anderson (1998), Punch (1998) and Tobin and Fraser (1998) list several strengths and advantages of each approach. Quantitative data enable standardized, objective comparisons to be made, and the measurements permit overall objective description of the situation. Qualitative methods, on the other hand, are flexible and they provide ways of getting the insider's perspective, (i.e. the meanings that people attach to things and events). Based on the above analysis, one can state that major differences between the two approaches lie in the nature of their data, and in the methods for collecting and analyzing data. I decided to use the strengths of each method in order to gain holistic understanding of the research questions.

Students' perceptions of the learning environment can provide more meaningful results than observations obtained from an occasional external observer. Fraser (1998a) states that students are at good vantage point to make judgements about classrooms because they have encountered many different learning environments and have enough time in a class to form accurate impressions. In my study, students' perceptions were the main source of information for both the quantitative and qualitative approach.

Research has shown that classroom environment assessments bear strong and consistent links with student achievement and attitudes (Aldridge & Fraser, 2000; Fisher, Henderson & Fraser, 1997; Fraser, Giddings & McRobbie, 1995; Fraser, McRobbie & Giddings, 1993; Freedman, 1997; Germann, 1988; Henderson, Fisher & Fraser, 1998; Lee & Fraser, 2002; Wong & Fraser, 1995). The association between classroom environment and student outcomes (achievement and attitudes) also was explored in my study.

1.2 Context of the Study

I have always wanted to design a student-centered activity in which other subjects could be integrated into a science hands-on activity. In 1997, I was given nine weeks of release time from the classroom to attend the Dade Academy for Teaching Arts (DATA)(located in Miami, Florida, USA) to work on an independent project. At this institute, I developed the concept of using human body measurements, also known as anthropometry, in a classroom setting. At first, my idea was to develop a laboratory activity only. However, after speaking to Dr Barry Fraser, my doctoral supervisor, I decided to include student attitudes and classroom learning environment as part of my original idea. I thought that his suggestion was important, because the affective domain is such an important component in education. In particular, students' achievement and attitudes toward specific subjects are believed to be related to the environment to which the students are exposed.

That original idea evolved into the present study, which involved evaluating a science activity that actively engages students in the process of gathering, processing and analyzing data derived from human body measurements. It required students to use their prior knowledge acquired in science, mathematics and computer classes to interpret the information derived from the study. In the classroom activities involving human body measurements, students used science process skills such as collecting data, organizing and interpreting data, measuring, observing, predicting, reasoning and thinking. The purpose of this research was to investigate the effectiveness of these student-centered activities in terms of students' achievement and attitudes and their perceptions of their science classroom environments.

The data collection included achievement, attitudes toward science, and perceptions of classroom learning environment. For the anthropometric portion of the study, an instructional laboratory activity guide was developed, given to all students in the researcher's classroom, and used to determine students' ability to make linear and circumference measurements of the human body, to organize data in tables, charts and graphs, and to analyze and interpret the data using descriptive statistics and predictive linear regression equations.

Anthropometry (from the Greek *anthropos* 'human' and *metron* 'measure') is the biological science of measuring the size, weight and proportions of the human body (Farkas, 1994). Anthropometry is an appropriate activity in the science classroom, because concepts in science and mathematics can be integrated and technological tools can be used to process data and to enhance and facilitate learning. It is important that students see connections among other subjects, such as science, mathematics and technology. In *Project 2061*, it is stated that science provides mathematics with interesting problems to investigate and mathematics provides science with powerful tools to use in analyzing data (American Association for the Advancement of Science, 1990, p. 17). In the present study, students were taught how to make anthropometric measurements during student-centered activities in which they had the opportunity to apply prior and new knowledge to gather, process and analyze data generated from the research.

The research was conducted at a senior high school in Miami, Florida (USA). Miami-Dade County Public Schools is the fourth largest school district of the United States, serving a population of 365,500 students distributed among 333 schools and with an operational budget of $4 billion dollars. Two of the goals and objectives of the school district strategic plan for 2000-2005 are, firstly, to improve student achievement, emphasizing reading, writing skills, mathematics, and science and, secondly, to create an effective learning environment (Miami-Dade County Public Schools District and School Profiles, 2000-2001).

The school where the research was conducted serves a diverse community, both culturally and socio-economically. It has a population of approximately 3,200 students, with the following demographic characteristics: 55% White, 23.4% Hispanics, 16.5 % African-American and 5% Asian/others. The study involved Grade 9 and 10 biology students.

Both quantitative and qualitative methods were used to generate answers for the same research problem as recommended by Tobin and Fraser (1998). The use of different-sized samples ('grain sizes') for different research questions in learning environment research (Fraser 1999) has been used in mixed-methods research (Aldridge & Fraser, 2000; Fraser & Tobin, 1991; Lee, 2001), and was used in the collection of quantitative and qualitative data in this study.

For the quantitative portion of the study, questionnaires were used to gather information on students' attitudes to science and their perceptions of the learning environment from 761 students in 25 classes. The survey instrument that was chosen to measure student attitudes towards science was based on selected items from the *Modified Fennema-Sherman Science Attitude Scales* (Doepken, Lawsky, & Padwa, 1993). The adapted version for this study consists of 24 items assessing the four scales of Personal Confidence about Science, Usefulness of the Subject Matter, Perception of Teacher's Attitudes and Attitude to Scientific Inquiry.

Student perceptions of their classroom learning environment were measured using an adapted version of the personal form of the *Science Laboratory Environment Inventory* (SLEI) (Fraser, Giddings, & McRobbie, 1995; Fraser, McRobbie & Giddings, 1993). The version used in my study consisted of four scales (Integration, Rule Clarity, Student Cohesiveness, and Material Environment), each containing six items. Refinement and validation of the survey instruments were carried out as part of my study by using item and factor analyses. Cronbach's alpha coefficient was used as a measure of each scale's internal consistency reliability. Factor analysis was used to check the structure or factorial validity of instruments.

For the cognitive portion of the study, three areas were considered: an instructional laboratory activity (anthropometry, with a sample size of 158 students), a biology pretest and posttest (sample size of 158 students), and the final report card grade in Biology for the school year 2000-2001 (sample size of 662). The differences in sample sizes for the achievement part of the research arose because the anthropometric laboratory was conducted as a pilot activity among students in the researcher's biology classes only. Effect sizes (pre-post differences divided by the pooled standard deviation) and significance tests (MANOVA) were used to evaluate the teaching method in terms of changes in student achievement.

In order to measure the impact of using the anthropometric activities on students' attitudes and classroom environment, a comparison was made between students using anthropometric activities and students not using anthropometric activities. Again, effect sizes and significance tests (MANOVA followed by *t*-tests) were calculated.

Gender-related differences also were explored for student achievement, attitudes and classroom environment, again using a series of multivariate analyses of variance (MANOVAs) for repeated measures, with gender as the independent variable and the other variables as dependent variables. The within-class gender mean was used as the unit of statistical analysis because it reduces confounding by having each class provide a matched pair consisting of the male mean and the female mean for each scale.

The qualitative portion was carried out by interviewing 24 students mainly through written interviews, but orally in some cases, and recorded via audiotape and then transcribed. The main purposes of the qualitative portion of the study were to get a better understanding of the students' perspectives and to try to confirm findings from the quantitative portion of the study.

1.3 Aims of the Study

Based on the conceptual framework and the context of the study described in the previous sections, the following four main aims were identified for the present study:

1. To validate generally-applicable questionnaires for assessing classroom learning environment and attitudes to science among senior high school students in Southern Florida, USA.

2. To evaluate the student-centered anthropometric activities in terms of:
   (a) student achievement

(b) student attitudes to science

(c) student perceptions of their classroom learning environment.

3. To investigate gender differences in students' achievement, attitudes and perceptions of classroom environment.
4. To investigate associations between the classroom learning environment and the student outcomes of achievement and attitudes.

1.4 Overview of the Study

The design and findings of this study are presented in five chapters. Chapter 1 delineates the four research aims and describes the context within which this study was carried out. It also describes the conceptual framework of the research.

In Chapter 2, in addition to a review of the diverse literature associated with this study, trends in learning environment research, the use of mixed methods (quantitative and qualitative), and historical and contemporary learning environment surveys (LEI, CES, ICEQ, CUCEI, QTI, CLES, WIHIC and SLEI) are described. The development, validation and use in past studies of the Science Laboratory Environment Inventory (SLEI) are explored in more detail. Also reviewed are studies into associations between classroom environments and students' attitudes, gender differences in science attitudes and perceptions of the learning environment, and the instructional use of other anthropometric activities.

In Chapter 3, sampling, data collection (survey and interview), and research methods (mixed) are discussed. A description is given of the methods of statistical analysis used to provide information about the validity and reliability of the science attitude and learning environment scales, an evaluation of the anthropometric activity, gender differences in achievement, attitudes and perceptions of the learning environment, and associations between students' outcomes and their perceptions of the classroom environment.

Chapter 4 reports the statistical analyses and results for the quantitative portion of the study (survey) and also the findings from the qualitative portion (interview). The validity and reliability of the environment and attitude surveys are reported. An evaluation of the anthropometric activities in terms of achievement, attitudes and classroom environment is reported. Changes in achievement, as measured by pretest and posttest results, are described. Attitudes to science and perceptions of classroom environment associated with anthropometric activities are also reported.

Chapter 5 provides discussions and conclusions related to the findings derived from the study. Also included in this chapter are the limitations and implications of the present study and recommendations for future research.

1.5 Contributions and Significance of the Study

My study involved the use of innovative anthropometric activities, which were evaluated in terms of their impact on student outcomes (attitudes and achievement) and on the classroom learning environment. The learning goals of this anthropometric activity reflect the vision promoted in the *National Standards in Science Education.* Based on students' achievement data on the anthropometric activities and their responses given in the interview, it appears that the activities are appropriate for the intended student population.

One of the key components of this study was the development and implementation of the innovative anthropometric laboratory activity, which was especially designed for this research. It entails the use of science process skills such as measuring different human bones, collecting class measurement data, and organizing and interpreting the data. Some of the mathematics and statistics skills that were incorporated into the study to provide meaningful answers included variables, ratio, graphing, predictive models, and central tendency and variations statistics. The integration of concepts in science, mathematics, statistics and technology gave students the opportunity to visualize the interdependency of several subjects in real-life situations. Hopefully, this type of student-centered instructional activity could motivate other science teachers to conduct similar activities in the classroom or involve their students in student-centered activities.

Another contribution of this study is to the field of integrated curriculum instruction. While most instructional curricular activities are subject specific, this study is interdisciplinary in nature because it effectively links concepts and skills from science, mathematics, statistics, and technology (graphing calculators and computers).

A unique feature of this research is that it had an evaluation component involving student performance, student attitudes, and the nature of the classroom learning environment.

Therefore, the study contributes to the field of learning environments research by adding another study to the limited research that has employed the classroom environment as a criterion of effectiveness in evaluating educational innovations (e.g., Teh & Fraser, 1994).

Chapter 2

LITERATURE REVIEW

2.1 Introduction

The study involved the evaluation of an instructional activity for high school science. The research was developed around four major goals. First, I wanted to validate the survey instruments used to gather information about students' attitudes to science and their perceptions of the learning environment. Secondly, an anthropometric laboratory activity was evaluated in terms of student performance, student attitudes to science and perceptions of the classroom learning environment. Thirdly, I investigated gender differences in students' achievement, attitudes and perceptions of the classroom environment. Fourthly, associations between the classroom learning environment and the student outcomes of performance and attitudes were investigated.

The literature review in this chapter is organized in eight sections. Section 2.2 reviews literature on instructional activities involving anthropometric; Section 2.3 discusses historical perspectives on the study of learning environments; Section 2.4 reviews studies of associations between outcomes and classroom environment; Section 2.5 is devoted to gender differences; Section 2.6 focuses on mixed methods; Section 2.7 describes classroom environment instruments (LEI, CES, ICEQ, CUCEI, QTI, CLES, WIHIC, and SLEI); Section 2.8 discusses the assessment of student attitudes (TOSRA and Fennema-Sherman Attitude Scale); and Section 2.9 summarizes the literature reviewed in the previous sections.

2.2 Instruction Involving Anthropometric Activities

In the classroom activity of human body measurements in this study (anthropometry), students used science process skills such as collecting data, organizing and interpreting data, measuring, observing, predicting, and using reasoning and thinking. They integrated concepts in science, mathematics, and statistics and used technological tools (graphing calculators, computers) to process the information.

Anthropometry, from the Greek *anthropos,* ('human') and *metron,* ('measure'), is the biological science of measuring the size, weight and proportions of the human body (Farkas, 1994). Anthropometry is an appropriate activity in the science classroom, because concepts in science and mathematics can be integrated and technological tools can be used not only to process data, but also to enhance and facilitate learning. It is important that students see connections among subjects, such as science, mathematics and technology. It is believed that there has always been a natural interconnection between science and mathematics. In *Project 2061*, it is stated that science provides mathematics with interesting problems to investigate and that mathematics provides science with powerful tools to use in analyzing data (American Association for the Advancement of Science, 1990).

Mosenthal and Kirsch (1994) stated that, before 1860, the belief was that each person's body was unique. They described how the outbreak of the Civil War produced a sudden demand for uniforms in great quantities. The army discovered that certain body measurements tended to recur in combination with predictable regularity. This simple discovery made it possible to manufacture well-fitting clothes for a large population. Such discoveries and practices gave rise to **anthropometry** or the measurement of the individual with a view of discovering those patterns of physical and mental characteristics which recur among people differing in such dimensions as age, gender, and economic status.

Some of the activities on anthropometry found in this literature review that have excellent applications in the classroom are provided by Greeley and Reardon-Offerman (1997), Knill (1981, 1995), Neufeld (1989), Pagni (1979) and Shaw (1984). A brief analysis of each is described below.

Neufeld (1989) carried out measurements and calculations of human body measurements with students from Grades 4 to 9, as well as with prospective teachers and teachers attending inservice courses. Calculations of body surface as well as volume and density were made. Neufeld states that students' measurements of their own bodies can enhance the teaching of measurement, and he considers that this activity should be based on concrete, pictorial, and abstract modes of instruction.

Greeley and Reardon-Offerman (1997) provide an excellent activity relating geometry to physical therapy. It refers to measuring angles of different joints in the student body in order to determine the range of motion. The data were entered and processed on a graphing calculator (TI-82). A step-by-step procedure of how to input the data in the graphing calculator is proposed. This activity was field tested with fifth graders and middle school mathematics classes.

Shaw (1984) describes various activities that provide practice in measuring skills, estimating, and computing area and volume of the human body. One of the activities, 'Primary Metric Me', is geared to Grades 1-3 and the other activity, 'Upper Grades Metric Me', is focused on Grades 4-8.

Knill (1995) also provides an excellent activity involving the use of mathematics in forensic science. This activity uses algebraic equations and graphing exercises as a means of interpreting forensic anthropometric data. It is very appropriate for the high school level. Knill (1981) states that, when a skeleton is found, a forensic scientist uses the length of certain bones to calculate the height of the living person. The bones that are used are femur (F), tibia (T), humerus (H), and radius (R).

Pagni (1979) describes activities using human variability. In one of the activities, he used discrete variables to describe, classify, and count genetic traits. In the other activity, he used measurable human characteristics that can be represented as continuous variables.

Perhaps one of the most comprehensive anthropometric studies is the one on product safety design for infants, children and youth aged up to age 18 years. In 1977, the Highway Safety Research Institute of the University of Michigan carried out this research for the U.S. Consumer Product Safety Commission (Highway Safety Research Institute, 1977). In this study, 87 body measurements were made of over 4000 subjects all across the United States taking into consideration race, gender, demographic, and socioeconomic factors. Scatter plots, regression coefficient and summary statistics such as mean, standard deviation, 5^{th}, 50^{th} and 95^{th} percentiles and minimum and maximum are given for each measurement. Highly-trained technicians carried out the research and they also used highly sophisticated anthropometric tools.

Boser, Faires, Slawson and Stevenson (1988) concur that the role of science teachers in determining the quality of the school science experience is very important. They stated that "relating classroom learning to practical application results in more positive student attitude, but this can occur only when the teachers are sensitive to the relationship between what is happening in their classroom and the world around them. In this way, students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills" (p. 3).

The anthropometric activities described in the literature review above, as well as those activities described in the present study, are the types of practical applications that are likely to get students interested in science and mathematics and possibly show more positive attitudes toward science and mathematics. The students involved in my study made anthropometric measurements as part of student-centered activities which required the application of prior and new knowledge to gather, process and analyze data generated from the research. This information was used to compile central tendency statistics (mean, mode, median), standard deviations and regression equations. The aim of this research was to investigate the effectiveness of the anthropometric activities, especially in terms of student achievement, attitudes and perceptions of the learning environment.

2.3 Historical Perspectives on the Study of Learning Environments

Lewin (1936) was probably the first to point out that human behavior (B) is a function of the interaction between the individual person (P) and his/her environment (E) as stated in his formula $B = f(P, E)$. Murray (1938) was the first to use Lewin's approach to propose a needs-press model, which refers to the interaction between person and environment. Murray's personal needs refer to a personal tendency to move in the direction of certain goals (alpha press), while the environment press provides an external view, which can support or suppress the personality needs (beta press). Stern, Stein and Bloom (1956) have adapted Murray's need-press model and proposed the terms *private* beta press (the view that each person has of the environment) and *consensual* beta press (view that members of a group hold about the environment). In designing classroom environment studies, researchers must decide whether their analyses will involve the perception scores obtained from individual students (*private* press) or whether these will be combined to obtain the average of the environment scores of all students within the same class (*consensual* press) (Fraser, 1998). The work by Lewin (1936) and Murray (1938) might have served as foundation for the development of the first learning environment scales.

Walberg's Learning Environment Inventory (LEI) (Walberg & Anderson, 1968) and Moos' Classroom Environment Scale (CES) (Moos 1974, 1979; Moos & Trickett, 1987) were among the earliest learning environment instruments. Details of Walberg's LEI and Moos' CES are provided in Section 2.7 (classroom survey instruments). Since the pioneering work of Walberg and Moos, research on classroom learning environment has grown extensively (Fraser, 1991b, 1998), as reflected in the literature reviewed elsewhere in this chapter.

A strong history of research on classroom learning environments (Fraser, 1991b, 1998) has established several trends relevant to the proposed study. First, several widely-applicable and carefully-validated questionnaires for assessing student perceptions of classroom environments formed the starting point for the development of the learning environment questionnaire used in the present study (see Section 2.7). Second, this study followed previous research (Maor & Fraser, 1996; Teh & Fraser, 1994) in which educational innovations have been evaluated in part in terms of their impact in transforming the classroom learning environment (see Section 2.2). Third, the study also replicated past research which has explored associations between the nature of the classroom learning environment and students' achievement and attitudes (Lee, 2001; McRobbie & Fraser, 1993; Talton & Simpson, 1986, 1987) (Sections 2.3, 2.4, and 2.8). Fourth, the study also investigated gender differences in the students' perceptions of their learning environment and their attitudes to science (Section 2.5).

2.4 Associations Between Outcomes and Classroom Environment

Because the fourth aim of my study involved investigating associations between the classroom learning environment and the student outcomes of performance and attitudes, this section reviews past research in this area.

Various studies have explored associations between students' perceptions of their learning environment and students' outcomes (attitudes and performance) (Aldridge & Fraser, 2000; Fisher, Henderson & Fraser, 1997; Fraser, Giddings & McRobbie, 1995; Fraser, McRobbie & Giddings, 1993; Freedman, 1997; Germann, 1988; Henderson, Fisher & Fraser, 1998; Lee & Fraser, 2002; Wong & Fraser, 1995).

Henderson, Fisher and Fraser (1998) reported that environmental science students' perceptions of cohesion, involvement, and task orientation were strongly associated with positive attitudinal outcomes. Freedman (1997) concluded that laboratory instruction influenced, in a positive direction, students' attitudes towards science and their achievement in science.

Johnson and Johnson (1991) stated that cooperative learning has been associated with indexes of student outcomes. Their definition of cooperative learning involves "the instructional use of small groups so that students work together to maximize their own and each other's learning" (p. 72). The authors caution us that cooperative learning activities work effectively if they are well planned and implemented.

Slavin (1983a, 1983b) concluded that the effects of cooperative learning on achievement are primarily motivational. That is, whereas little evidence supports that working in small groups per se is more or less effective that studying individually, it appears that working with others to achieve a group goal creates peer norms supporting learning and these increase student motivation to achieve and help one another.

Lazarowitz and Hertz-Lazarowitz (1998) provide an excellent overview of cooperative learning methods. They state that the development of cooperative learning instructional methods followed the reform of school desegregation in the late 1960s and early 1970s. They also mentioned that cooperative learning is necessary because science teachers are challenged by students' diversity in academic ability, motivation, needs, interests, future careers and values.

Other research on classroom environment also has focused on associations between students' cognitive and affective learning outcomes and their perceptions of psychosocial characteristics of their classrooms (Fraser & Fisher, 1982; Haertel, Walberg & Haertel, 1981; McRobbie & Fraser, 1993). When Fraser (1994) reviewed over 40 studies in science education, he found that associations between outcome measures and classroom environment perceptions have been replicated for a variety of cognitive and affective outcome measures, a variety of classroom environment instruments and a variety of samples.

Several researchers have used the SLEI (Science Laboratory Environment Inventory), the questionnaire used in my study, to investigate associations between students' cognitive and affective outcomes. These associations have been established for a sample of 80 senior high school chemistry classes in Australia (Fraser & McRobbie, 1995; McRobbie & Fraser, 1993), for 489 senior high school biology students in Australia (Fisher, Henderson & Fraser, 1997) and for 1592 grade 10 chemistry students in Singapore (Wong & Fraser, 1996), for 497 chemistry students in Singapore (Quek, Fraser & Wong, 2001), 644 chemistry students in Brunei Darussalam (Riah & Fraser, 1998), and 439 science students in Korea (Lee & Fraser, 2002).

By using an instrument suited for computer-assisted instruction classrooms, Teh and Fraser (1995a) established associations between classroom environment, achievement and attitudes among 671 high school geography students in 24 classes in Singapore. Using the QTI, associations between student outcomes and perceived patterns of teacher-student interaction have been reported with 489 senior high school biology students in Australia (Fisher, Henderson & Fraser, 1995), 3994 high school science and mathematics students in Australia (Fisher, Fraser & Rickards, 1997) and 1512 primary school mathematics students in Singapore (Goh, Young & Fraser, 1995). Meta-analyses conducted by several groups of researchers have provided further evidence supporting the link between educational environments and student outcomes (Fraser, Walberg, Welch & Hattie, 1987; Haertel, Walberg & Haertel, 1981).

In my study, I investigated associations between several cognitive outcomes (anthropometric test, Biology posttest and Biology final report card grade), several attitudinal outcomes (Personal Confidence About Science, Usefulness of Subject Content, Perception of Teachers Attitudes and Attitudes to Scientific Inquiry) and students' perceptions of the classroom environment as assessed by the Science Laboratory Environment Inventory (SLEI).

2.5 Gender Differences

The third goal of this study was to investigate gender differences in the way students perceived their learning environment and in their achievement and attitudes toward science. Various studies point to gender differences in how the learning environment and attitudes to science are perceived by students (Arambula, 1995; Catsambis, 1995; Fraser, Giddings, & McRobbie, 1995; Henderson, Fisher, & Fraser, 1998; Weinburgh, 1995; Zerega, Haertel, Tsai & Walberg, 1986). Variables such as achievement, attitude, motivation, interest, and performance have been used in studies of gender differences (Beverly & Farenga, 1999; Dimitrov, 1999; Hatchell, 1998; Morrell & Lederman, 1998).

Beverly and Farenga (1999) found that males are more likely to select physical sciences and that perceptions of science as an appropriate or inappropriate field of study are developed before the age of nine years. Hatchell (1998) stated that the expectations and attitudes of science teachers play an important role in relation to how students positioned themselves. She found that encouragement was an essential ingredient of education, including the way in which female students positioned themselves or were positioned in the science classroom. Morrell and Lederman (1998) examined 5th, 7th, and 10th graders' attitudes toward school and classroom science. Their results indicated that females were slightly more positive about school than males. No gender differences were found with respect to classroom attitudes. Fifth graders held significantly more positive attitudes toward science than upper-grade students did.

McCarty and Baird (1997) investigated the influence of 17 factors on high school students' attitudes toward women in science. They found that student gender, science ability, level of education, plans to complete high levels of education and career interest accounted for 24.6% of total variance. They also found that, as students' science skills and ability increase, so do students'attitudes toward women in science.

Dimitrov (1999) conducted research on 2551 fifth graders from 40 schools to determine patterns of gender differences in science achievement across response formats (multiple-choice and open-ended) and strands of learning outcomes (earth and space science, nature of science, physical sciences and life science). He found that gender differences in science achievement of fifth graders did not depend on ethnicity. For high-ability students, boys outperformed girls only on the open-ended questions for physical sciences.

Gender differences in science students' perceptions of classroom environment have been reported in several studies (Aldridge, Fraser, Fisher & Wood, 2002; Fraser, Giddings & McRobbie, 1995; Henderson, Fisher & Fraser, 1998; Lawrenz, 1987; Margianti, Fraser & Aldridge, 2002; McRobbie, Giddings & Fraser, 1990; Raaflaub & Fraser, 2002; Zerega, Haertel, Tsai & Walberg, 1986).

Fraser, Giddings and McRobbie (1995) investigated gender differences in perceptions of learning environment by using the Science Laboratory Environment Inventory (SLEI) for a sample of 258 students in 29 classes. They found that females generally perceived the science laboratory environment more favorably that did males for both the actual and preferred forms of SLEI. This finding replicates past research (Lawrenz, 1987; McRobbie, Giddings & Fraser, 1990).

Henderson, Fisher and Fraser (1998) used the ESLEI (Environmental Science Learning Environment Inventory) with a sample of 100 students in environmental science classes in Tasmania and found statistically significant sex-related differences in students' perceptions of their learning environment. Females perceived greater levels of Cohesion, Integration, Task Orientation, and Involvement, and a more favorable Material Environment.

Aldridge, Fraser, Fisher and Wood (2002) reported gender differences in perceptions of a technology-rich learning environment, using a sample size of 386 students in 33 classes. They found that girls perceived a more positive classroom environment than do boys, primarily in terms of Student Cohesiveness, Cooperation, Equity and Young Adult Ethos.

Raaflaub and Fraser (2002) used the WIHIC (What is Happening In this Classroom) questionnaire to investigate gender differences in the learning environment in Canadian mathematics and science classrooms in which laptop computers were used. They found that females' learning environment scores were higher than males' scores for Teacher Support, Cooperation and Equity.

Margianti, Fraser and Aldridge (2002) conducted a study using an Indonesian version of the WIHIC with a sample of 2498 students in 50 university mathematics classes. They reported that the magnitudes of differences between males and females students' perceptions of the actual learning environment were small, with female students perceiving significantly more Order and Organization, Task Orientation and Cooperation than male students. Male students, on the other hand, perceived significantly more Equity than their female counterparts.

2.6 Mixed Methods

In the present study mixed methods (quantitative and qualitative methods) were used to generate answers for the same research problem as recommended by Tobin and Fraser (1998). Several authors and researchers in the field of education are increasingly recommending combining quantitative and qualitative methods in the same study (Anderson & Arsenault, 1998; Erickson, 1998; Fraser & Tobin 1991; Lee 2001; Punch, 1998; Tobin & Fraser, 1998).

Quantitative information was obtained from instruments assessing students' achievement and attitudes to science and their perceptions of science classroom psychosocial environment. Qualitative data (students' interviews) were used to complement information provided in the surveys.

Within the quantitative approach (use of questionnaires), the study was conceptualized in terms of variables and relations between them, while the qualitative approach (interviews) provided a way of getting the subjects' views (Erickson, 1998). Anderson and Arsenault (1998) provide a list of strengths and weaknesses of quantitative and qualitative methods, which was used as a guide for selecting positive aspects of each method.

Punch (1998) mentioned several approaches to combining qualitative and quantitative methods. One of these approaches, 'qualitative research facilitates quantitative research', seems to be appropriate for the scope of this investigation.

Fraser and Tobin (1991) point out some merits of combining qualitative and quantitative methods in learning environments research by drawing on three case studies of successful attempts at using questionnaire surveys and ethnographic methods together within the same investigation in science education. Houtz (1995) used sequential triangulation methods (mixed methods) to investigate differences between the middle school and the junior high school in terms of instructional strategies and the effects of adolescents' attitudes towards school on science achievement.

The use of different-sized samples ('grain sizes') for different research questions in learning environment research has been used in previous mixed-methods research (Aldridge & Fraser, 2000; Fraser 1999; Fraser & Tobin, 1991; Lee, 2001), and was used in the collection of quantitative and qualitative data in this study.

2.7 Classroom Environment Instruments

An overview of several instruments for assessing students' perceptions of classroom psychosocial environment has been provided in several sources (Fraser, 1986, 1998; Fraser & Walberg, 1991).

A brief overview of eight widely-applicable classroom environment instruments used in high school and higher education is given in Table 2.1 (adapted from Fraser, 1998). The scales in these eight instruments are classified in Table 2.1 using Moos' (1974) scheme for classifying human environments. Moos' three types of dimensions are Relationship Dimensions (which identify the nature and intensity of personal relationships within the environment and assess the extent to which people are involved in the environment and support and help each other), Personal Development Dimensions (which assess basic directions along which personal growth and self-enhancement tend to occur) and System Maintenance and System Change Dimensions (which involve the extent to which the environment is orderly, clear in expectations, maintains control and is responsive to change).

Table 2.1 Overview of Scales in Eight Secondary/Higher Education Classroom Environment Instruments (LEI, CES, ICEQ, CUCEI, QTI, SLEI, CLES and WIHIC) (Adapted from Fraser, 1998)

Instrument	Level	Items per Scale	Relationship Dimensions	Personal Development Dimensions	System Maintenance/ Change Dimensions
Learning Environment Inventory (LEI)	Secondary	7	Cohesiveness Friction Favoritism Cliqueness Satisfaction Apathy	Speed Difficulty Competitiveness	Diversity Formality Material Environment Goal Direction Disorganization Democracy
Classroom Environment Scale (CES)	Secondary	10	Involvement Affiliation Teacher Support	Task Orientation Competition	Order and Organization Rule Clarity Teacher Control Innovation
Individualized Classroom Environment Questionnaire (ICEQ)	Secondary	10	Personalization Participation	Independence Investigation	Differentiation
What Is Happening In this Classroom? (WIHIC)	Secondary	8	Student Cohesiveness Teacher Support Involvement	Investigation Task Orientation Cooperation	Equity
College and University Individualization Classroom Environment Inventory (CUCEI)	Higher Education	7	Personalization Involvement Student Cohesiveness Satisfaction	Task Orientation	Innovation
Questionnaire on Teacher Interaction (QTI)	Secondary/ Primary	8-10	Helpful/Friendly Understanding Dissatisfied Admonishing		Leadership Student Responsibility and Freedom Uncertain Strict
Science Laboratory Environment Inventory (SLEI)	Upper Secondary/ Higher Level	7	Student Cohesiveness	Open-Endedness Integration	Rule Clarity Material
Constructivist Learning Environment Survey (CLES)	Secondary	7	Personal Relevance Uncertainty	Critical Voice Shared Control	Student Negotiation

A brief description of each of the eight classroom environment surveys listed in Table 2.1 is given below.

2.7.1 Learning Environment Inventory (LEI)

The initial development and validation of LEI began in 1960 in conjunction with evaluation and research associated with Harvard Project Physics (Fraser, Anderson & Walberg, 1982; Walberg & Anderson, 1968). This original version of LEI evolved from Walberg's Classroom Climate Questionnaire (Walberg, 1968).

The final version of the LEI contains a total of 105 statements distributed among seven scales. The survey uses a four-point scale with the response alternatives of *Strongly Disagree, Disagree, Agree* and *Strongly Agree.* For example, the meaning of the Cohesiveness scale is the extent to which students know, help and are friendly towards each other. Material Environment refers to the availability of adequate books, equipment, space and lighting.

2.7.2 Classroom Environment Scale (CES)

The CES (Moos & Trickett, 1987) was originally part of Rudolf Moos' Social Climate Scales developed at Stanford University to assess a variety of human environments such as university residences, hospitals, correctional institutions, military companies, families, social and therapeutic groups, work environments and classroom environments (Moos, 1974).

The original version of CES consisted of 242 items representing 13 conceptual dimensions (Trickett & Moos, 1973). The final version of the CES contains nine scales (Involvement, Affiliation, Teacher Support, Task Orientation, Competition, Order & Organization, Rule Clarity, Teacher Control and Innovation) with 10 items of True-False response format. For example, Involvement is the extent to which students have attentive interest, participate in discussions, do additional work and enjoy the class, and Rule Clarity is the emphasis on clear rules, on students knowing the consequences for breaking rules, and on the teacher dealing consistently with students who break rules.

2.7.3 Individualized Classroom Environment Questionnaire (ICEQ)

Although the LEI and CES paved the way for the development of other classroom environment surveys, these instruments did not include dimensions salient in individualized classrooms. Therefore, to fill this important void, the ICEQ was developed to assess those dimensions, such as Personalization and Participation, which distinguish individualized classrooms from conventional classrooms involving either open or inquiry-based approaches. The initial long version of ICEQ (Rentoul & Fraser, 1979) was subjected to field testing and item analyses and later modified to form a shorter final version (Fraser, 1990), which contains 50 items and five scales (Personalization, Participation, Independence, Investigation and Differentiation). The response to each item is based on a five-point scale with the alternatives of *Almost Never, Seldom,* *Sometimes, Often,* and *Very Often.* For example, Personalization refers to the emphasis on opportunities for individual students to interact with the teacher and on concern for the personal welfare and social growth of the individual, and Independence refers to the extent to which students are allowed to make decisions and have control over their own learning and behavior.

2.7.4 College and University Classroom Environment Inventory (CUCEI)

This instrument was developed to gather information in higher education classrooms. It was designed to assess perceptions in small class settings, and not for lectures or laboratory classes (Fraser & Treagust, 1986; Fraser, Treagust & Dennis, 1986). The initial version of CUCEI used some of the salient dimensions from three surveys used at the secondary classroom level, namely, the LEI, CES and ICEQ.

The final version of CUCEI has seven scales (Personalization, Involvement, Student Cohesiveness, Satisfaction, Task Orientation, Innovation and Individualization), each containing seven items. Each item has the four possible responses of *Strongly Agree, Agree, Disagree,* and *Strongly Disagree* (Fraser, 1998).

2.7.5 Questionnaire on Teacher Interaction (QTI)

The original version of the QTI was developed in the Netherlands and focuses on the nature and quality of interpersonal relationships between teachers and students (Creton, Hermans & Wubbels, 1990; Wubbels, Brekelmans & Hooymayers, 1991). The QTI is based on a theoretical model of proximity (cooperation–opposition) and influences (dominance–submission) and was developed to assess student perceptions of eight behavior aspects. Each item has a five-point response scale ranging from Never to Always (Fraser, 1998).

Cross-validation and comparative work on the QTI has been carried out in other countries such as the USA (Wubbels & Levy, 1993), Australia (Fisher, Henderson & Fraser, 1995), Singapore (Goh & Fraser, 1996), Brunei (Riah, Fraser & Rickards, 1997), Korea (Lee, 2001) and Indonesia (Soerjaningsih, Aldridge & Fraser, 2002).

2.7.6 Constructivist Learning Environment Survey (CLES)

The CLES (Taylor, Dawson & Fraser, 1995; Taylor, Fraser & Fisher, 1997) was developed to assist researchers and teachers to assess the degree to which a particular classroom's environment is consistent with a constructivist epistemology, and to assist teachers to reflect on their epistemological assumptions and reshape their teaching practice (Fraser, 1998). The CLES has five scales (Personal Relevance, Uncertainty, Critical Voice, Shared Control and Student Negotiation). Each item has a five-point response scale of *Almost Never, Seldom, Sometimes, Often* and *Almost Always.*

The factor structure and/or reliability of the CLES have been established in several countries, including Australia, Taiwan, the USA and Korea (Adams, 1998; Aldridge, Fraser, Taylor & Chen, 2000; Cho, Yager, Park & Seo, 1997; Dryden & Fraser, 1998; Kim, Fisher & Fraser, 1999; Lee & Fraser, 2002; Poth & Fraser, 2000; Spinner & Fraser, 2002).

2.7.7 What is Happening in This Class? (WIHIC)

The WIHIC was developed by drawing on salient scales from other existing classroom environment questionnaires and by including additional scales that contain contemporary issues such as equity and constructivism (Fraser, Fisher & McRobbie, 1996). The original version, containing 90 items distributed among nine scales, was refined by statistical analyses and interviews and later modified to the final version. The final version consists of seven dimensions (Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, and Equity), with eight items in each scale, for a total of 56 items.

The factor structure for the WIHIC has been established in several countries, including Australia, Taiwan, Singapore, Brunei, Indonesia, Canada, the USA and Korea (Aldridge, Fraser & Huang, 1999; Allen & Fraser, 2002; Chionh & Fraser, 1998; Lee, 2001; Margianti, Fraser, & Aldridge, 2002; Raaflaub & Fraser, 2002; Riah & Fraser, 1998).

2.7.8 Science Laboratory Environment Inventory (SLEI)

Because the SLEI was chosen for use in my study, it is discussed below in some detail in two separate subsections: its initial development and validation (Section 2.7.8.1); and its use in past research (Section 2.7.8.2).

2.7.8.1 Development and Validation of SLEI

All of the survey instruments discussed above assess the classroom learning environment, but they are not specifically designed for measuring student perceptions of the science laboratory class. To fill this void, the Science Learning Environment Inventory (SLEI) was developed and validated (Fraser, Giddings & McRobbie 1995; Fraser & McRobbie, 1995; Fraser, McRobbie & Giddings, 1993). The initial 72-item version of SLEI contained seven scales (Teacher Supportiveness, Student Cohesiveness, Open-Endedness, Integration, Organization, Rule Clarity and Material Environment) and was field tested simultaneously in six countries (Australia, USA, Canada, England, Nigeria and Israel) with a sample size of 4643 students in 225 individual laboratory classes. The initial version was developed in a 'class' form, which involved an individual student's perceptions of the class as a whole.

The authors of SLEI saw the need to develop a 'personal' form that would involve a student's perceptions of his or her own role within the class. The Personal form of the SLEI was developed (Fraser, Giddings & McRobbie, 1995), cross-nationally field tested with 5447 students in 269 senior high school and university classes in six countries (USA, Canada, England, Israel, Australia and Nigeria), and cross-validated with 1594 senior high school students in 92 classes in Australia (Fraser & McRobbie, 1995), 489 senior high school biology students in Australia (Fisher, Henderson & Fraser, 1997), 1592 grade 10 chemistry students in Singapore (Wong & Fraser, 1995, 1996), for 497 chemistry students in Singapore (Quek, Fraser & Wong, 2001), 439 high school science students in

Korea (Lee & Fraser, 2002); and 644 chemistry students in Brunei Darussalam (Riah & Fraser, 1998).

The final version of the SLEI consists of 35 items distributed evenly among five scales (Student Cohesiveness, Open-Endedness, Integration, Rule Clarity, and Material Environment). Each item has the five response alternatives of *Almost Never, Seldom, Sometimes, Often,* and *Very Often.* This final version has a Personal actual form and a Personal preferred form. The authors mentioned several advantages of using SLEI: its 35 items can be administered in 15 minutes; the printing cost is low; and the questionnaire's items are arranged in cyclic order to permit easy hand scoring.

A modified version of SLEI was used in this study. A description of the modified version is given in Chapter 3.

2.7.8.2 Past Studies Using SLEI

McRobbie, Giddings and Fraser (1990) first used SLEI with a sample of 4643 students in 225 individual laboratory classes. They explored associations between student attitudes and classroom environment and found that the dimensions of the SLEI were related positively with student attitudes (the only exception being that Open-Endedness was related negatively to attitudes for some subsamples). In their analysis of gender differences, they found that girls appeared to prefer a more favorable classroom environment than the one preferred by boys on most SLEI dimensions.

Fraser, Giddings and McRobbie (1995) used the Personal and Class form of SLEI, whose main advantage is that it is more sensitive for studying subenvironments within classes (e.g. target students or gender subgroups). The authors found that both the Class and Personal forms displayed satisfactory internal consistency reliability, discriminant validity, and factorial validity in both their actual and preferred versions when either the individual student's score or the class mean score was used as the unit of analysis. The results of their study also showed that open-ended activities are the exception rather than the rule in science laboratory classes around the world. Their investigation of gender differences in student perceptions of science laboratory classroom environments replicated past research in that females' views generally were more positive than males' views. The results of their study of associations between student outcomes and their perceptions of their science laboratory classroom environments also replicated past research in that there were statistically significant associations between the nature of the laboratory environment and several attitudinal outcomes.

Henderson, Fisher and Fraser (1998) used a modified version of SLEI, called the ESLEI (Environmental Science Learning Environment Inventory), to measure students' perceptions of their learning environment in senior environmental science classrooms involving 100 students in seven classes in Tasmania. Statistically significant associations between students' perceptions on the set of learning environment scales and attitudinal outcomes were found. They also found statistically significant sex-related differences in students' perceptions of their learning environment, with females perceiving greater levels of Student Cohesion, Integration, Task Orientation, Involvement, and Material Environment than did males.

Wong and Fraser (1995) also reported similar gender differences and positive associations between laboratory environment and students' attitudinal outcomes among secondary chemistry students in Singapore. These results were replicated in later studies involving Singaporean chemistry students by Quek, Fraser, & Wong, (2001) and Bruneian chemistry students (Riah & Fraser, 1998).

Fisher, Henderson and Fraser (1997), in a study involving 489 senior secondary students in 28 biology classes in Tasmania, found that students' attitude scores were higher in classrooms where students perceived greater Student Cohesiveness, Integration and Rule Clarity and a more favorable Material Environment.

Lee and Fraser (2002) used a Korean translation of the SLEI to investigate 439 Korean high school students' perceptions of their laboratory classrooms from three different streams (humanities, science-oriented and science-independent). They found that students from the science-independent stream perceived their classroom environments more favorably that did students in the other two streams. They found that students' attitudes to science are more likely to be positive in laboratory classes where students perceive greater Student Cohesiveness, Integration and Rule Clarity. The findings from their survey and interviews confirmed that students perceive that laboratory lessons are closely associated with theory lessons and that they have clear rules.

Henderson and Fisher (1998) outline several ways in which secondary science teachers could use the SLEI for evaluating aspects of their own science laboratory environments. First, it can be used to monitor students' views of the changes that teachers make to the laboratory environment in order to try to achieve greater congruence between students' actual and preferred laboratory environments. Second, to increase students' ratings on the Open-Endedness scale, a teacher might give students more opportunities for individual experimentation, formulating their own hypothesis and designing experiments to test these hypotheses, and using the results of their experiments to solve inquiry-based problems. Third, in order to increase students' rating on the Integration scale, a teacher could place greater emphasis on the importance of a particular practical investigation for concepts covered in theory, refer to the results of key experiments when they are relevant to work covered later in the course, and provide students with more problems to solve using the results of their practical investigations. Fourth, in order to increase students' ratings on the Student Cohesiveness scale, teachers might give greater emphasis to group work in class, which would enable students to work more closely together, to cooperate with one another in laboratory activities, and to share ideas and opinions. Fifth, in order to increase students' ratings on the Rule Clarity scale, a teacher could provide clear guidelines about the use of the laboratory for experimental work, regularly remind students about the guidelines, and carefully monitor students' behavior during practical investigations. Sixth, to increase students' ratings for the Material Environment scale, a teacher could endeavor to improve the physical appearance of the laboratory, to ensure that adequate equipment is readily available for each student, and to ensure that students make maximum use of the facilities and the space in the laboratory. Seventh, the SLEI can also be used to quantify differences among students of different sexes, abilities or ethnic backgrounds in the way in which they perceive their learning environment.

Given the nature of the dimensions assessed by the SLEI, together with its impressive validation statistics and extensive use in past research, the SLEI was chosen for use in the present study.

2.8 Assessment of Students' Attitudes

Historically, the concept of attitude has been extensively explored by Shrigley, Koballa and Simpson (1988), who stated that the word attitude is derived from '*aptus*' (Latin) which means 'fitness' or 'adaptedness' in its physical connotation (aptitude). However, attitude also has a mental connotation, in that it refers to 'a mental preparation for action as well'.

In addition to students' perceptions of the classroom learning environment, students' attitudes to science are also important criteria when evaluating educational innovations. In the present study, one scale from the TOSRA (Test of Science Related Attitudes) was used in conjunction with the Modified Fennema-Sherman Attitude scales to gather information about students' attitudes to science.
The Test of Science Related Attitudes (TOSRA) was designed to measure seven distinct science-related attitudes among high school students (Fraser, 1981). The theoretical foundation for TOSRA came from Klopfer's (1971) categories for the affective domain in science education and are represented in the seven TOSRA scales: Social Implication 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. Several researchers have reported that factor analysis has revealed that three

scales of the TOSRA (Leisure Interest in Science, Career Interest in Science, and Enjoyment of Science Lessons) have high intercorrelations, which means that they measure overlapping dimensions and therefore all three can be fused into a single scale for most research purposes (Fraser, 1981; Khalili, 1987; Schibeci & McGaw, 1981). Fraser (1981) stated that this high intercorrelation among the three scales is expected because there is a tendency for a student who enjoys science lessons to be more likely to have a leisure and career interest in science. Because of the overlap between some TOSRA scales, some researchers have decided to select only some of the scales in the TOSRA, rather than using all the scales (Aldridge, Fraser, Taylor, & Chen, 2000; Lee, 2001; Wong & Fraser, 1996).

Another survey instrument that was chosen to measure student attitudes towards science was based on selected items from the *Modified Fennema-Sherman Science Attitude Scales* (Doepken, Lawsky, & Padwa, 1993). The original version of the Modified Fennema-Sherman Attitude Scales has 47 items distributed among four different scales (Personal Confidence about the Subject Matter, Usefulness of the Subject's Content, Subject Perceived as a Male Domain, and Perception of Teacher's Attitudes). Chapter 3 provides further information about the scales used to measure students' attitudes to science in my study.

2.9 Chapter Summary

This chapter was devoted to reviewing literature that as a foundation for gaining a better understanding of previous research relevant to my study. This includes anthropometry, students' perceptions of classroom learning environment, students attitudes to science, gender differences in students' achievement and attitudes, and students' perceptions of learning environment, the use of mixed methods in educational research, and instruments for assessing classroom environment, and attitudes to science.

Literature dealing with anthropometry that was reviewed covered science process skills, such as collecting data, organizing and interpreting data, measuring, observing, predicting, reasoning and thinking, all of which have been used in the classroom activities involving human body measurement (anthropometry). The literature dealing with the use of anthropometric activities in the classroom served as foundation for developing the instructional materials that were used in the present study.

The third section provided a historical perspective on the field of learning environments. Starting with the conceptual framework laid out by Murray and Lewin, the pioneering work of Walberg and Moos in developing two of the first learning environment scales was discussed.

The fourth section described research that has established consistent associations between students' perceptions of their learning environment and students' outcomes (attitudes and achievement). This line of research formed the fourth research question in my study.

The fifth section dealt with studies of gender differences in the way in which students perceive their learning environment and in their attitudes to science. Typically, females have been found to perceive more positive learning environments than their male counterparts in the same classrooms. My study's third research question focused on gender differences.

The sixth section discussed the combination of qualitative and quantitative research methods to answer the same research questions, including the importance of using mixed methods.

The seventh section reviewed eight widely-applicable instruments for measuring students' perceptions of the learning environment (LEI, CES, ICEQ, CUCEI, QTI, CLES, WIHIC, and SLEI) for use at the high school and higher education levels. Because the SLEI was selected for the present study, its initial development, validation and use in past studies was considered in detail.

The last section discussed student attitudes to science. Because one scale from the TOSRA (Test of Science Related Attitudes) was used in conjunction with the Modified Fennema-Sherman Attitude scales to gather information about students' attitudes to science in the present study, literature related to these instruments was discussed.

Chapter 3
METHODS

3.1 Introduction

Chapter 1 identifies the major goals of this study:

1. To validate generally-applicable questionnaires for assessing classroom learning environment and attitudes to science among senior high school students in southeastern USA.
2. To evaluate student-centered anthropometric activities in terms of:
   (a) student achievement
   (b) student attitudes to science.
   (c) student perceptions of their classroom learning environment.
3. To investigate gender differences in students' achievement, attitudes and perceptions of classroom learning environment.
4. To investigate associations between the classroom learning environment and the student outcomes of achievement and attitudes.

This chapter describes the research methods, sample size, procedures for collecting data, survey instruments and how the data were analyzed. The chapter is organized into six sections. Section 3.2 describes the research design. Section 3.3 deals with sample size and procedures for data collection. Section 3.4 describes the evaluation instruments. Section 3.5 describes the student interviews, section 3.6 explains how the data were analyzed, and section 3.7 gives a summary of the chapter.

3.2 Research Design

In the present study, mixed methods were used (quantitative and qualitative methods) to generate answers for the same research problem as recommended by Tobin and Fraser (1998). Quantitative information was obtained from questionnaires assessing student attitudes to science and their perceptions of science classroom psychosocial environment. Qualitative data (students' interviews) were used to complement information provided in the surveys.

Within the quantitative approach (use of questionnaires), the study was conceptualized in terms of variables and relations between them, while the qualitative approach (interviews) provided a way of getting the subjects' views (Erickson, 1998). Anderson and Arsenault (1998) provide a list of the strengths and weaknesses of quantitative and qualitative methods, and this was used as a guide for selecting positive aspects of each method.

Punch (1998) mentioned several approaches to combining qualitative and quantitative methods. One of these approaches, 'qualitative research facilitates quantitative research', seems an appropriate description of the methods used in my investigation.

Several authors and researchers in the field of education are increasingly recommending combining quantitative and qualitative methods in the same study (Anderson, 1998; Erickson, 1998; Fraser & Tobin, 1991; Lee, 2001; Punch, 1998; Tobin & Fraser, 1998). Fraser and Tobin (1991) point out the merits of combining qualitative and quantitative methods in learning environments research by drawing on three cases of successful attempts at using questionnaire surveys and ethnographic methods together within the same investigation in science education. Houtz (1995) used sequential triangulation methods (mixed methods) to investigate differences between middle school and the junior high instructional strategies and the effects of adolescents' attitudes towards school on science achievement.

The use of different-sized samples ('grain sizes') for different research questions in learning environment research (Fraser 1999) has been used in mixed-methods research (Aldridge & Fraser, 2000; Fraser & Tobin, 1991; Lee, 2001), and was used in the collection of quantitative and qualitative data in this study (see sample size in Section 3.3).

Fraser (1998) stated that academic achievement by itself does not give a complete picture of the educational process. He considers that students have a large stake in what happens to them at school and that their reactions to and perceptions of their school experience should be taken into account. Based on this claim, it was decided that students' input in terms of their attitudes to science and their perception of classroom environment would be incorporated into my study to provide a more complete picture of the education process.

3.3 Sample and Data Collection

The study involved different sample sizes for investigating different research questions. For research questions 1, 3 and 4 (see section 3.1), a sample size of 761 students in 25 classes was used. These research questions referred to validating the science attitude and classroom environment survey, investigating gender differences in achievement, attitude and perceptions of learning environment, and investigating associations between classroom learning environment and the student outcomes of performance and attitudes.

The second research question involved evaluating the effectiveness of the anthropometric activity in terms of student achievement and attitudes and the classroom environment. Different parts of this research question involved different sample sizes. The cognitive portion of the study involved three areas: performance on an instructional laboratory activity (anthropometry) with a sample size of 158 students, a Biology achievement test with a sample size of 598 students, and the final report card grade in Biology for the school year 2000-2001 involving a sample size of 662. The differences in sample sizes for the achievement part of the research arose because the anthropometric laboratory was conducted as a pilot activity among a limited number of students in the researcher's biology classes only. Although we intended to have the same sample size for both the Biology achievement test and the final report card grade in biology, this was not possible because some students where absent either for only the pretest or the posttest or were only present for one of the two achievement tests.

The part of the study involving the anthropometric activity was conducted at a suburban public high school in the southeastern part of the United States. This school serves a diverse community, both culturally and socio-economically. It has a population of approximately 3200 students (2001 school profile), with the following demographic characteristics: 55% White, 23.4% Hispanics, 16.5 % African-American and 5% Asian/others. For the school year 2000-2001, the 2375 students who were enrolled in at least one honors or advanced placement class were 62% White, 23% Hispanics, 8% Black and 7% Asian/Others. This comparison shows, that despite the impressive number of students taking honors and Advanced Placement classes, Afro-American participation in such high-level coursework is very low.

For the qualitative part of the research, a group of 24 students (11 girls and 13 boys) were selected to participate in the interviews. These target students are all honors students in the researcher's biology classes. These students were selected because they are more involved in classroom interactions, they are high achievers and they seem to have no problem in providing honest responses. They all had experienced the anthropometric laboratory activity.

Student feedback formed the basis for the qualitative part of the study. The qualitative data were collected mostly through written interviews. Students were provided with a list of written questions and they were asked to respond in writing. After I read their responses, if more in depth information was required or if clarification was needed, then an oral interview was carried out. Oral interviews were recorded on audiotape and then transcribed. In order to optimize the credibility of interviews, as recommended by Erickson (1998), the transcriptions were shown to students, and revised subsequently.

The purposes of the interviews were twofold. First, we wanted to expand on and gain clarification of some of the responses given on the attitude questionnaire and environment survey (quantitative portion of the study). Second, we wanted to assess students' opinions about the anthropometric activities.

3.4 Evaluation Instruments

This section describes the attitude scales (section 3.4.1), classroom environment scales (section 3.4.2) and achievement measures (section 3.4.3) used in my study.

3.4.1 Attitude Survey (Modified Fennema-Sherman Science Attitude Scales)

As part of the quantitative portion of this study, a survey was used to gather information from a large number of students in science classrooms via sampling procedures and statistical analysis. The survey was used to gather data on students' attitudes to science.

The survey instrument that was chosen to measure student attitudes towards science was based on selected items from the *Modified Fennema-Sherman Science Attitude Scales* (Doepken, Lawsky, & Padwa, 1993). The original version of the Modified Fennema-Sherman Attitude Scales has 47 items in four different scales (Personal Confidence about the Subject Matter, Usefulness of the Subject's Content, Subject Perceived as a Male

Domain, and Perception of Teacher's Attitudes). Literature related to this questionnaire is reviewed in Chapter 2.

I adapted this version of the attitude instrument to yield 24 items and the four scales of: Personal Confidence about Science, Usefulness of the Subject Matter, Perception of Teacher's Attitudes, and Attitude to Scientific Inquiry. The Attitude to Scientific Inquiry scale was taken from the Test of Science-Related Attitudes (TOSRA) (Fraser, 1981). Each scale consists of 6 items, 3 of them having a positive scoring direction and 3 having a negative scoring direction. Each item is based on a five-point Likert scale with the response alternatives of *Strongly Agree, Agree, Not Sure* or *Can't Answer, Disagree* and *Strongly Disagree.* A copy of the Attitude survey is given in Appendix A.

Validation and refinement of the adapted version of the Modified Fennema-Sherman Science Attitude Scales were carried out by using item and factor analyses. For example, a small number of the original items were removed because their factor loading was lower than 0.40 on their own scale.

3.4.2 Learning Environment Survey (Science Laboratory Environment Inventory)

When teaching science classes, the laboratory activity is important because it gives students the opportunity to conduct practical tasks. The dynamics that take place in a science laboratory are very different from what happens in a regular science class. Because the anthropometric activity is purely a laboratory activity, it was considered desirable to use a survey instrument that was able to measure students' perceptions of the psychosocial environment of the science laboratory.

Student perceptions of their classroom learning environment were measured using an adapted version of the personal form of *Science Laboratory Environment Inventory* (SLEI) (Fraser, Giddings, & McRobbie, 1995; Fraser, McRobbie & Giddings, 1993). The original version of SLEI has 35 items distributed among five different scales (Student Cohesiveness, Open-Endedness, Integration, Rule Clarity and Material Environment), with seven items in each scale. Some of the questions have a positive scoring direction and some have a negative scoring direction. Each item is based on a five-point response scale with the alternatives of Almost *Never, Seldom, Sometimes, Often* and *Very Often.* The literature review in Chapter 2 gives additional information on past studies using SLEI.

In the present research, the original SLEI was modified. The version used in this study consists of four scales (Integration, Rule Clarity, Student Cohesiveness, and Material Environment), containing six items in each scale. Only four scales were chosen based on their relevance to the purposes of my research.

The authors of SLEI (Fraser, McRobbie, & Giddings, 1993) have successfully field tested and validated it simultaneously with a sample of over 5400 students in 269 classes in six different countries (USA, Canada, England, Israel, Australia and Nigeria). The authors also report strong factorial validity for SLEI with their sample. The factor structure has been cross-validated by researchers in other countries with 1594 Australian students in 92 classes (Fraser & McRobbie, 1995), 489 senior high school biology students in Australia (Fisher, Henderson & Fraser, 1997), 1592 high school chemistry students in Singapore (Wong & Fraser, 1995), and 439 high school science students in Korea (Lee & Fraser, 2002). However, because the present study made use of a modified version of SLEI, it was desirable to cross-validate it. A copy of the survey SLEI is given in Appendix A.

A description of each scale in the Science Learning Environment Inventory (SLEI), together with a sample item for each scale, is given in Table 3.1.

Table 3.1 Description and Sample Item for each Scale in the Modified Science Laboratory Environment Inventory (SLEI)

Scale Name	Description	Sample Item
Student Cohesiveness	Extent to which student know, help and are supportive of one another	I work cooperatively in laboratory sessions. (+)
Integration	Extent to which the laboratory activities are integrated with non-laboratory and theory classes.	We use the theory from our regular science class session during laboratories activities. (+)
Rule Clarity	Extent to which behavior in the laboratory is guided by formal rules.	There is a recognized way of doing things safely in this laboratory. (+)
Material Environment	Extent to which the laboratory equipment and materials are adequate	The laboratory equipment which I use is in poor working condition. (-)

For items designated (+), scoring is as follows: *almost never* (1), *seldom* (2), *sometimes* (3), *often* (4), and *very often* (5). Items designated (-) are scored in the reverse manner. Omitted or invalid responses are scored 3.

Table 3.2 shows the scale allocation and scoring direction for each item of the environment survey. A copy of this survey is given in Appendix A.

Table 3.2 Scale Allocation and Scoring Direction for Each Item of Attitude Survey and Environment Survey

Science Attitude Scales				Science Environment Scales			
Personal Confidence about Science	Usefulness of Subject Content	Perception of Teachers Attitudes	Attitudes to Scientific Inquiry	Integration	Rule Clarity	Student Cohesiveness	Material Environment
1 (+)	2 (+)	3 (+)	4 (+)	25 (+)	26 (+)	27 (+)	28 (-)
5 (+)	6 (+)	7 (+)	8 (+)	29 (+)	30 (+)	31 (+)	32 (+)
9 (+)	10 (+)	11 (+)	12 (+)	33 (-)	34 (+)	35 (+)	36 (-)
13 (-)	14 (-)	15 (-)	16 (-)	37 (+)	38 (+)	39 (+)	40 (-)
17 (-)	18 (-)	19 (-)	20 (-)	41 (-)	42 (-)	43 (+)	44 (+)
21 (-)	22 (-)	23 (-)	24 (-)	45 (-)	46 (-)	47 (-)	48 (-)

Each positive item receives a score based on the following: A = 5 B = 4 C = 3 D = 2 E = 1
Negative questions should be reversed as follows: A = 1 B = 2 C = 3 D = 4 E = 5

3.4.3 Achievement Measures

To gather information about student achievement, three areas were considered: performance on an instructional laboratory activity (anthropometry), a Biology test administered on two occasions (pretest and posttest), and the final report card grade in Biology for the school year 2000-2001.

The anthropometric instructional laboratory activity was designed specifically for this research study and was used to determine student ability to make linear and circumference measurements of the human body, and to organize data in tables, charts and graphs. It was also used to analyze and interpret the data by use of descriptive statistics and to develop predictive linear regression equations by using graphing calculators. The Anthropometric task was administered as a pretest and posttest before and after the instructional laboratory activity was taught to determine if changes in achievement occurred. A copy of the anthropometry laboratory guide is given in Appendix B, a copy of the anthropometric test is given in Appendix C, a copy of the anthropometry background information is given in Appendix D, and instructions on how to input data with a graphing calculator can be found in Appendix E.

The final report card grade in Biology for the school year 2000-2001 was collected and used as a measure of achievement and also to determine its association with classroom environment. It refers to student grades on the mandated curricular content taught by all science teachers during the school year.

And, lastly, a pretest and posttest administration of a Biology test were part of the achievement portion of the study. The Biology pretest was administered at the beginning of the school year (September 2000) and the posttest was given at the end of the school year (May 2001). For the school year 2000-2001, the administrators at the high school where this research was conducted decided to implement the pretest and posttest in Biology as part of the school improvement plan. The test consists of 40 multiple-choice questions. It covers concepts related to the scientific method, the chemical basis of life, cell structure and function, genetics and diversity of life. The purpose of the test was to determine students' prior knowledge (pretest) and growth in knowledge (changes between pretest and posttest). A copy of the Biology pretest/posttest is given in Appendix F.

3.5 Student Interviews

The quantitative information obtained through surveys was complemented by qualitative data gathered through interviews. I considered that combining quantitative and qualitative methods to gather information on the same research questions would provide a more holistic understanding of the students' attitudes to science and their perceptions of the science learning environment.

The interview process was based on questions related to the anthropometric activities, student views of cooperative learning groups, and student views about the future science classes in which they would like to enroll over the next three years of high school. A copy of the interview questions is given in Appendix G, a copy of the student consent form is given in Appendix H, and the authorization form from the district office that gave permission to conduct the research can be found in Appendix I.

Twenty-four students (13 boys and 11 girls) were selected from the researcher's honors biology classes for the qualitative component of the research involving interviews. It was decided that it was important to obtain feedback about students' views of the laboratory setting, because the anthropometric task is a laboratory activity. The interview also provided additional information to enhance interpretation of the quantitative data.

As mentioned elsewhere, the qualitative data were collected primarily through written interviews. The purposes of the interviews were twofold. First, I wanted to expand and gain clarification about some of the responses given on the attitude questionnaire and environment surveys (quantitative portion of the study). Second, I wanted to obtain further information about students' perceptions of the anthropometric activities.

3.6 How the Data Were Analyzed

In order to achieve the four main goals of the research proposed in section 3.1, quantitative and qualitative data were collected and analyzed.

Quantitative data were gathered through surveys and analyzed for the following four purposes identified in section 3.1: to determine the validity and reliability of the attitude and classroom environment instruments; to evaluate the anthropometric activities in terms of student achievement, student attitudes to science, and student perceptions of their classroom learning environment; to investigate gender differences in attitude to science, classroom environment and achievement; and to explore associations between student outcomes (achievement and attitudes) and dimensions of the classroom environment as assessed with the SLEI.

3.6.1 Validity and Reliability of Instruments

The first research objective deals with validating the survey instruments that measured perceptions of classroom learning environment and students' attitudes to science. The statistical methods used to establish validity and reliability of the instruments are discussed below.

3.6.1.1 Reliability

Reliability refers to the consistency of the measuring instrument. The reliability of a measure tells us how much error variance is in a score. The larger the reliability, the smaller the error, and conversely the smaller the reliability, the larger the error. Reliability is based on two aspects: consistency over time (stability) and internal consistency (the extent to which the items are consistent with each other, or are working in the same direction). For this study, only the internal consistency reliability was investigated.

The internal consistency reliability of each scale of SLEI and the attitude survey was determined by using Cronbach's alpha coefficient (Cronbach, 1951). The results for the internal consistency of the scales are described in Chapter 4.

3.6.1.2 Validity

Both reliability and validity are central concepts in measurement. Validity refers to the extent to which an instrument measures what it is claimed to measure. There is always an inference involved between the indicators that we can observe (or the items to which people respond) and the construct that we aim to measure.

The two basic ways of validating and refining survey instruments are: item analysis and factor analysis. Data were subjected to item analysis in order to identify items whose removal would enhance each scale's internal consistency and discriminant validity (the extent to which a scale measures a unique dimension not covered by the other scales in the instrument). The mean correlation of a scale with the other scales was used as a convenient index of discriminant validity.

Factor analysis is typically used to support the scale structure of a survey instrument. The Statistical Package for Social Studies (SPSS) was used to carry out principal components factor analysis with varimax rotation. The individual student was used as the unit of analysis. The only items retained in this study were those that have a factor loading of 0.40 or greater on their own scale, and a factor loading of less than 0.40 on all other scales. Factor analysis results are reported in Chapter 4.

Analysis of variance (ANOVA) was used to determine the ability of each classroom environment scale to differentiate between the perceptions of students in different classes. The eta^2 statistic was calculated to provide an estimate of the strength of association between class membership and the dependent variable (SLEI) scales. The eta^2 is a measure of the proportion of variance accounted for by class membership and is computed as the ratio of 'between' to 'total' sums of squares.

3.6.2 Evaluation of Anthropometric Activities

This section refers to the second goal of the research, which was to evaluate the student-centered anthropometric laboratory activities in terms of student achievement, student attitudes to science and student perceptions of their laboratory learning environment.

For achievement, a pretest-posttest design permitted me to trace changes that occurred in performance over time. However, only a limited sample size of 158 students was available for this analysis. In contrast to the pretest-posttest design used with achievement outcomes, only a single assessment of student attitudes and classroom environment was made. Therefore, it was more difficult to gauge the impact of using the anthropometric activities on students' attitudes and classroom environment. However, because a large sample had responded to the attitude and environment scales, it was possible to compare the attitudes and classroom environment scores of students undertaking the anthropometric activities (186 students) with a comparison group of students who were following the traditional curricular program (574 students).

These data were analyzed by conducting a separate MANOVA, followed by *t*-tests, for achievement, attitudes and classroom environment. Because the achievement measures involved a pretest-posttest design, it was necessary to use a MANOVA for repeated measures and *t*-tests for paired samples. Importantly, effect sizes (the difference in means expressed in standard deviation units) were also calculated to provide information about the magnitudes of effects. Average item means (the scale mean divided by the number of items) were used to permit meaningful comparison as scales containing differing numbers of items.

Three measures of academic achievements were used: a Biology achievement test; the score for the laboratory activity on the anthropometric task; and the Final Report Card grade in Biology.

For the school year 2000-2001, the administrators at the high school where this research was conducted decided to implement a pretest and posttest in biology as part of the school improvement plan. The test consists of 40 multiple-choice questions encompassing the scientific method, the chemical basis of life, cell structure and function, genetics and diversity of life. The purpose of the test was to determine students' prior knowledge (pretest) and growth in knowledge (changes between pretest and posttest). The pretest was administered at the beginning of the school year (September 2000) and the posttest was administered at the end of the school year (May 2001).

For the anthropometric portion of the study, an instructional laboratory activity guide was developed, given to all students in the researcher's classroom, and used to determine student ability to make linear and circumference measurements of the human body, to organize data in tables, charts and graphs, and to analyze and interpret the data using descriptive statistics and predictive linear regression equations. Pretests and posttests were administered before and after the instructional activities to determine if improvements in knowledge and understanding had occurred.

The anthropometric laboratory is based on an activity in which student had to measure the length of different bones of their body, then collect information from the rest of the class, organize the data in charts and graphs and then use a graphing calculator to determine statistical correlation between different variables and compute predictive regression equations. A sample of the laboratory guide is given in Appendix B. The anthropometric pretest was done at the beginning of May 2001 and the posttest at the end of May 2001. The laboratory activity was carried out during the month of May.

3.6.3 Gender Differences in Achievement, Attitudes and Perceptions of Learning Environment

The third objective of this research was to investigate gender differences in students' achievement, attitudes and perceptions of classroom environment. The statistical analyses used to accomplish this goal are described in this section.

As mentioned in the previous section, three sources of information were used to determine gender differences in academic achievement. Student achievement was assessed using Final Report Card grade in Biology (this refers to student final coursework grade in Biology) and the Biology achievement posttest score. Because of the limited sample size (158 students), gender differences in performance on the anthropometric test were not investigated. Whereas the SLEI was used to assess students' perceptions of their classroom environment, an attitude survey was used to assess four aspects of student attitudes to science.

A separate MANOVA followed by *t*-tests was used to investigate the statistical significance of gender differences for achievement, for attitudes and for classroom environment. The within-class gender mean was used as the unit of analysis, with gender as the repeated-measures independent variable and the other variables as dependent variables. Because the multivariate test yielded a statistically significant result using Wilks' lambda criterion in every case, a *t*-test for paired sample was conducted for each dependent variable. Using the within-class gender mean avoids confounding by providing for each class a matched pair of means (consisting of the males' mean and the females' mean). Average item means were used to permit meaningful comparisons between scales when there are differences in the number of items in the different scales. Effect sizes (differences in means divided by the pooled standard deviation) were used to estimate the magnitude of gender differences.

3.6.4 Associations Between Students' Outcomes and their Classroom Environment Perceptions

Another goal of this research was to investigate associations between the students' outcomes of achievement and attitudes and their perceptions of the learning environment. Associations between students' perceptions of their classroom environment and student outcomes (achievement and attitudes) were investigated by use of simple correlation and multiple regression analyses using two units of analysis (individual and class). Simple correlation (*r*) was used to describe the bivariate association between each outcome (achievement or attitude) and each SLEI scale. The standardized regression weight β was used to characterize the association between an outcome (achievement or attitude) and a particular learning environment scale when all other SLEI scales are mutually controlled.

3.7 Chapter Summary

This chapter describes the research methods, sample sizes, procedures for collecting data, interviews, survey instruments, and how the data were analyzed.

Overall, the methods of the present study can be described as a mixture of quantitative and qualitative approaches. Different grain sizes were used to answer different research questions. Over 700 students responded, via survey, to the science attitude and learning classroom environment questionnaires. A sample almost this size also provided achievement data. However, the subgroup involved specifically in the anthropometric activities and achievement test was only 158 students. This represents the quantitative portion of the study. Qualitative data (24 students' interviews) were used to complement information provided in the surveys.

The survey instrument that was chosen to measure student attitudes towards science was based on selected items from the *Modified Fennema-Sherman Science Attitude Scales* (Doepken, Lawsky, & Padwa, 1993). The adapted version for this study consists of 24 items assessing the four scales of Personal Confidence about Science, Usefulness of the Subject Matter, Perception of Teacher's Attitudes and an Attitude to Scientific Inquiry.

Student perceptions of their classroom learning environment were measured using an adapted version of the personal form of the *Science Laboratory Environment Inventory* (SLEI) (Fraser, Giddings, & McRobbie, 1995; Fraser, McRobbie & Giddings, 1993). The version used in this study consists of four scales (Integration, Rule Clarity, Student Cohesiveness, and Material Environment), each containing six items.

Refinement and validation of the survey instruments were carried out by using item and factor analyses. Cronbach's alpha coefficient was used as a measure of each scale's internal consistency reliability. Factor analysis was used to check the structure or factorial validity of instruments. Also ANOVA was computed to determine whether the SLEI could differentiate between the perceptions of students in different classrooms.

The second research objective involves an evaluation of the anthropometric activities in terms of achievement, attitudes and environment. For the cognitive portion of the study, three areas were considered: achievement in an anthropometric laboratory activity; a Biology achievement test; and the Final Report Card grade in Biology for the school year 2000-2001. A pretest-posttest design was used with the subsample of 158 students who experienced the anthropometric activities. Effect sizes (pre-post differences divided by the pooled standard deviation) and significance tests (MANOVA followed by t-tests for paired samples) were used to evaluate the teaching method in terms of changes in student achievement.

In order to measure the impact of using the anthropometric activities on students' attitudes and classroom environment, a comparison was made between students using anthropometric activities and students not using anthropometric activities. Again, effect sizes and significance tests (MANOVA followed by t-tests) were calculated.

Gender-related differences were explored for student achievement, attitudes and classroom environment using a series of multivariate analyses of variance (MANOVAs) for repeated measures, with gender as the independent variable and the other variables as dependent variables. Because the multivariate test yielded a statistically significant result using Wilks' lambda criterion in each case, a t-test for paired sample was conducted separately for each dependent variable. The within-class gender mean was used as the unit of statistical analysis because it reduces confounding by having each class yield a matched pair consisting of the male mean and the female mean for each scale.

And, lastly, associations between students' perceptions of their classroom environment and student outcomes (attitudes and achievement) were investigated by use of simple correlation and multiple regression analyses for two levels of analysis (the student and the class).

Chapter 4

ANALYSES AND RESULTS

4.1 Introduction

As previously mentioned in chapter 1 of this thesis, the major aims of this study were the following:

1. To validate generally-applicable questionnaires for assessing classroom learning environment and attitudes to science among senior high school students in southeastern USA.
2. To evaluate student-centered anthropometric activities in terms of:
   (a) student achievement
   (b) student attitudes to science.
   (c) student perceptions of their classroom learning environment.
3. To investigate gender differences in students' achievement, attitudes and perceptions of classroom learning environment.
4. To investigate associations between the classroom learning environment and the student outcomes of achievement and attitudes.

To provide answers to these aims, a sample of 761 students distributed among 25 classes responded to the attitude and environment questionnaires and 24 students were interviewed.

This chapter reports data analyses and results, using six major sections: Section 4.2 describes the validity and reliability of the classroom environment and attitude instrument; Section 4.3 discusses the evaluation of anthropometric activities in terms of achievement, attitudes and classroom environment; Section 4.4 focuses on gender differences in achievement and attitude measures; Section 4.5 deals with associations between students' outcomes and their classroom environment perceptions; Section 4.6 reports student opinions of the anthropometric activities based on interviews; and Section 4.7 provides a summary of the chapter.

4.2 Validity and Reliability of Environment and Attitude Questionnaires

As mentioned previously, one of the goals of the research was to validate the adapted versions of the Science Learning Environment Inventory (SLEI) and the Modified Fennema-Sherman Attitude Scales that were used in this study. Item analyses and factor analyses were used to refine and validate the survey instruments. The validity and reliability are discussed for the environment survey in Section 4.2.1 and for the attitude survey in Section 4.2.2.

4.2.1 Validity and Reliability of SLEI (Science Laboratory Environment Inventory)

In the present research, I used a modified version of the SLEI consisting of four scales (Integration, Rule Clarity, Student Cohesiveness, and Material Environment), containing six items in each scale. The scale Open-Endedness was purposely omitted from the modified version because most of the laboratory classes at the school in which my research was undertaken are dominated by closed-ended activities. Although the original version of SLEI has been extensively cross-validated, it was deemed necessary to conduct validation studies for the modified version with the present sample of 761 students from a high school in the South Eastern part of the United States.

When using a survey instrument, a common procedure is to check its reliability by using Cronbach's alpha coefficient (Cronbach, 1951), which is an index of internal consistency (the extent to which items in the same scale measure the same dimension). Item analysis was used for the four scales and 24 items of SLEI using both the individual student and the class mean as the units of analyses. When using the individual student as the unit of analysis, alpha coefficients ranged from 0.79 to 0.86 and, when using the class means as the unit of analysis, reliabilities ranged from 0.90 to 0.95 (Table 4.1). In both cases, these coefficients easily exceed the threshold of 0.60, which is often considered as acceptable for research purposes (Nunnally, 1967).

Table 4.1 Internal Consistency Reliability (Cronbach Alpha Coefficient) for Two Units of Analysis and Ability to Differentiate Between Classrooms (ANOVA Results) for the SLEI

Scale	No. of Items	Unit of Analysis	Alpha Reliability	ANOVA Eta^2
Integration	6	Individual	0.80	0.08**
		Class Mean	0.93	
Rule Clarity	6	Individual	0.80	0.12**
		Class Mean	0.90	
Student Cohesiveness	6	Individual	0.86	0.09**
		Class Mean	0.95	
Material Environment	6	Individual	0.79	0.13**
		Class Mean	0.91	

** $p<0.01$ The sample consisted of 761 students in 25 classes. The eta^2 statistic (which is the ratio of 'between' to 'total' sums of squares) represents the proportion of variance explained by class membership

An analysis of variance (ANOVA) was performed for each scale of the SLEI to assess each scale's ability to differentiate between the perceptions of students in different classrooms. The last column in Table 4.1 shows the result of the analysis in terms of the eta^2 statistic (which is the ratio of 'between' to 'total' sums of squares and represents the proportion of variance explained by class membership). The value of the eta^2 statistic was statistically significant ($p<0.01$) for each scale and ranged from 0.08 to 0.13 for different scales, suggesting that each scale of the SLEI was able to differentiate between the perceptions of students in different classes.

Although several other authors have reported strong support for the factor structure of the SLEI (Fraser, McRobbie & Giddings, 1993; Lee, 2001; Wong & Fraser, 1996), I was unable to replicate this structure with the present sample. Nevertheless, because of the

SLEI's established factorial validity, the *a priori* four-scale structure was used in all analyses.

4.2.2. Validity and Reliability of the Modified Fennema-Sherman Attitude Scale

A factor analysis (principal components with varimax rotation) was conducted for the 24 attitude items in four scales for the total sample of 761 biology students. It was found that three items from the scale Perception of Teachers Attitudes had a factor loading lower than 0.40 with its own scale (namely, Items 3, 7, and 11). It was decided to omit Items 3 and 11 in all subsequent analyses, but to retain Item 7.

The results for the factor loadings for the final factor analysis are shown in Table 4.2. For 23 of the 24 items in Table 4.2, the factor loading is greater than 0.40 for the scale to which the item belongs and less than 0.40 with any other scale. As noted above, the factor loading is smaller than 0.40 for Item 7. Also Table 4.2 shows that all 24 items have a factor loading smaller than 0.40 with all other scales (except the *a priori* scale).

Table 4.2 reveals that a total of 44% of the variance could be accounted for by all four interpretable factors. Personal Confidence About Science and Usefulness of Subject Content accounted for 11.44% and 13.13% of the variance, respectively, while Perception of Teachers' Attitudes and Attitudes to Scientific Inquiry accounted for 9.40% and 9.91% of the variance, respectively. Overall, the analysis reported in Table 4.2 provides strong support for the factorial validity of the attitude questionnaire.

Table 4.2 Factor Loadings for the Science Attitude Scales

	Factor Loading			
Item No.	Personal Confidence about Science	Usefulness of Subject Content	Perception of Teachers' Attitudes	Attitudes to Scientific Inquiry
1	0.60			
5	0.65			
9	0.67			
13	0.52			
17	0.64			
21	0.45			
2		0.64		
6		0.63		
10		0.58		
14		0.50		
18		0.75		
22		0.67		
7			—	
15			0.64	
19			0.70	
23			0.52	
4				0.71
8				0.60
12				0.60
16				0.41
20				0.55
24				0.59
% Variance	11.44	13.13	9.40	9.91

Factor loadings smaller than 0.40 have been omitted from this analysis.
The sample consisted of 761 students.

Table 4.3 shows the internal consistency reliability and discriminant validity for the science attitudes scale for two units of statistical analysis — the individual and the class mean.

Item analysis was used for the four scales and 22 items of refined Attitude Scale using both the individual student and the class as the units of analyses. When using the individual student as the unit of analysis, alpha reliability coefficient ranged from 0.67 to

0.83 and, when using the class means as the unit of analysis, the coefficient ranged from 0.74 to 0.93 (Table 4.3). These coefficients exceed the value of 0.60, which is considered as acceptable for research purposes (Nunnally, 1967). However, these values are somewhat lower than those obtained for the SLEI and reported previously in Table 4.1.

The discriminant validity (using the mean correlation of a scale with other scales as a convenient index) ranged from 0.26 to 0.42 when using individual student as the unit of analysis and from 0.55 to 0.77 when using class mean as the unit of analysis (Table 4.3). This suggests that raw scores on each scale assess a unique, although somewhat overlapping, dimension. However, the factor analysis results attest to the independence of factor scores.

Table 4.3 Internal Consistency Reliability (Cronbach Alpha Coefficient), Discriminant Validity (Mean Correlation With Other Scales) for Two Units of Analysis for the Science Attitude Scales

Scale	No. of Items	Unit of Analysis	Alpha Reliability	Mean Correlation with other Scales
Personal Confidence about Science	6	Individual	0.81	0.42
		Class Mean	0.87	0.77
Usefulness of Subject Content	6	Individual	0.83	0.42
		Class Mean	0.93	0.92
Perception of Teachers Attitudes	4	Individual	0.67	0.38
		Class Mean	0.93	0.73
Attitudes to Scientific Inquiry	6	Individual	0.76	0.26
		Class Mean	0.74	0.55

** $p<0.01$ The sample consisted of 761 students in 25 classes

4.3 Evaluation of Anthropometric Activities in Terms of Achievement, Attitudes and Classroom Environment

This section refers to the second goal of the research, which was to evaluate the student-centered anthropometric laboratory activities in terms of student performance, student attitudes to science and student perceptions of their laboratory learning environment. Whereas Section 4.3.1 reports analyses involving student achievement, Section 4.3.2 reports analyses involving students' attitudes to science and their perceptions of their classroom learning environment.

4.3.1 Changes in Achievement

Analysis of achievement data was accomplished by conducting *t*-tests for paired samples for changes between pretest and posttest for two achievement measures.

Two sources of information were used to assess academic achievement: Biology score (involving a comparison of pretest and posttest scores to measure increase in achievement since the time of the pretest), and the score for the anthropometric laboratory activity (specially designed for this research) which also involved a pretest-posttest design.

For the school year 2000-2001, the administrators at the high school where this research was conducted decided to implement a pretest and posttest in Biology as part of the school improvement plan. The test consisted of 40 multiple-choice questions. It covers concepts related to the scientific method, the chemical basis of life, cell structure and function, genetics and diversity of life. The purpose of the test was to determine students' prior knowledge (pretest) and growth in knowledge (changes between pretest and posttest). The pretest was administered at the beginning of the school year (September 2000) and the posttest was administered at the end of the school year (May 2001). Five hundred and ninety-eight (598) students took this test both as a pretest and posttest. However, analyses were restricted to the subsample of 158 students who had experienced the anthropometric laboratory activity. The Biology test can be found in Appendix F.

The anthropometric laboratory test is based on an activity in which student had to measure the length of different bones of their body, then collect information from the rest of the class, organize the data in charts and graphs, and then use a graphing calculator to determine statistical correlation between different variables and to compute predictive regression equations. A sample of the laboratory guide is given in Appendix B. The pretest was done at the beginning of May 2001 and the posttest at the end of May 2001. A copy of the anthropometry pretest/posttest is given in Appendix C. The laboratory activity was carried out during the month of May. One hundred fifty-eight (158) students participated in the anthropometric activity and tests.

Table 4.4 reports the average item mean, average item standard deviation and *t*-test for paired samples for the difference between pretest and posttest scores for both Biology and anthropometric achievement using the individual as unit of analysis.

Table 4.4 Average Item Mean, Average Item Standard Deviation, and Difference Between Pretest and Posttest Scores (Effect Size and *t*-Test for Paired Samples) in Biology and Anthropometric Achievement with the Individual as the Unit of Analysis

Scale	Average Item Mean Score		Average Item Standard Deviation		Differences Between Pre and Posttest Scores	
	Pretest	Posttest	Pretest	Posttest	Effect Size	*t*
Biology	1.19	1.47	0.34	0.37	0.80	-20.28**
Anthropometric	1.20	2.46	1.14	1.20	1.08	-12.97**

*$p<0.05$ **$p<0.01$
The sample size used for these analyses was 158 students.

Table 4.4 shows that the average item mean score for the Biology pretest was 1.19 and for the posttest score was 1.47. The posttest showed an increase of 24% over the pretest. The *t*-test for paired samples for differences between the pretest and posttest scores in Biology revealed statistically significant results ($p<0.01$) (Table 4.4). In order to estimate the magnitudes of the differences (in addition to their statistical significance), effect sizes were calculated as recommended by Thompson (1998a, 1998b). The effect size for the change in Biology scores between pretest and posttest was over three quarters of a standard deviation (0.80) with the individual as the unit of analysis, which suggests a substantial difference between the pretest and posttest scores.

Table 4.4 also shows that the average item mean on the anthropometric activity was 1.20 for the pretest and 2.46 for the posttest. The posttest score is approximately double the pretest score (Table 4.4). A *t*-test for paired samples for differences between the pretest and posttest scores on the anthropometric measure indicates statistically significant changes ($p<0.01$) (Table 4.4). The effect size of 1.08 for the individual as the unit of analysis also suggests a substantial difference between the pretest and posttest anthropometry scores.

4.3.2 Attitudes and Classroom Environment Associated with Anthropometric Activities

In contrast to the pretest-posttest design used with the achievement outcomes, only a single assessment of student attitudes and classroom environment was made. Therefore, it was more difficult to gauge the impact of using the anthropometric activities on students' attitudes and classroom environment. However, because a large sample had responded to the attitude and environment scales, it was possible to compare the attitudes and classroom environment scores of students undertaking the anthropometric activities (186 students) with a comparison group of students who were following the traditional curricular program (574 students).

Table 4.5 shows the average item mean, average standard deviation and difference between students using anthropometric activities and students not using anthropometric activities in terms of their attitudes to science and their perceptions of the classroom environment. Also results for t-test for independent samples and effect sizes are shown. As mentioned elsewhere, average item means were used to permit meaningful comparisons between scales when there are differences in the number of items in the different scales.

Table 4.5 Average Item Mean, Average Standard Deviation and Difference (Effect Size and *t*-Test for Independent Samples) Between Students Using and Not Using Anthropometric Activities in Attitudes to Science and Classroom Environment with the Individual as the Unit of Analysis

Scale	Average Item Mean		Average Item Standard Deviation		Difference	
	Students Using Anthropometric Activities	Students Not Using Anthropometric Activities	Students Using Anthropometric Activities	Students Not Using Anthropometric Activities	Effect Size	*t*
Attitudes to Science						
Personal Confidence about Science	2.25	2.09	0.71	0.70	0.23	2.70**
Usefulness of Subject Content	2.56	2.39	0.76	0.81	0.22	2.62**
Perception of Teachers' Attitudes	2.47	2.31	0.69	0.76	0.22	2.72**
Attitudes to Scientific Inquiry	2.56	2.39	0.73	0.76	0.23	2.68**
Classroom Environment						
Integration	3.43	3.45	0.79	0.87	0.02	-0.32
Rule Clarity	3.58	3.55	0.86	0.99	0.03	0.46
Student Cohesiveness	3.49	3.38	0.92	0.10	0.22	1.29
Material Environment	3.62	3.48	0.82	0.89	0.16	2.08*

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

N= 186 students who were using anthropometric activities and 574 who were not

The results in Table 4.5 show that there are statistically significant ($p<0.01$) differences in the responses given by the two groups of students on the attitude to science survey. The students who participated in the anthropometric activities showed a higher average item mean on all four scales of the attitudes to science survey, namely, Personal Confidence about Science, Usefulness of Subject Content, Perception of Teachers' Attitudes and Attitudes to Scientific Inquiry. The effect sizes for all four scales of the attitude survey were over one fifth of a standard deviation (0.22), suggesting modest differences between students who participated in the anthropometric activities and those who did not participate.

In terms of their perceptions of the science laboratory environment, only one scale, namely, Material Environment, showed statistical significant ($p<0.05$) difference between the two groups of students. The effect size for Material Environment was approximately one-sixth (0.16) of a standard deviation (Table 4.5).

Figure 4.1 and Figure 4.2 show a graphical representation of the magnitude of the differences between the two groups of students in terms of their attitudes to science and their perceptions of the classroom environment. Overall, these comparisons (Table 4.5 and Figures 4.1 and 4.2) provided support for the positive influence of using anthropometric activities on both students' attitudes and their classroom learning environment.

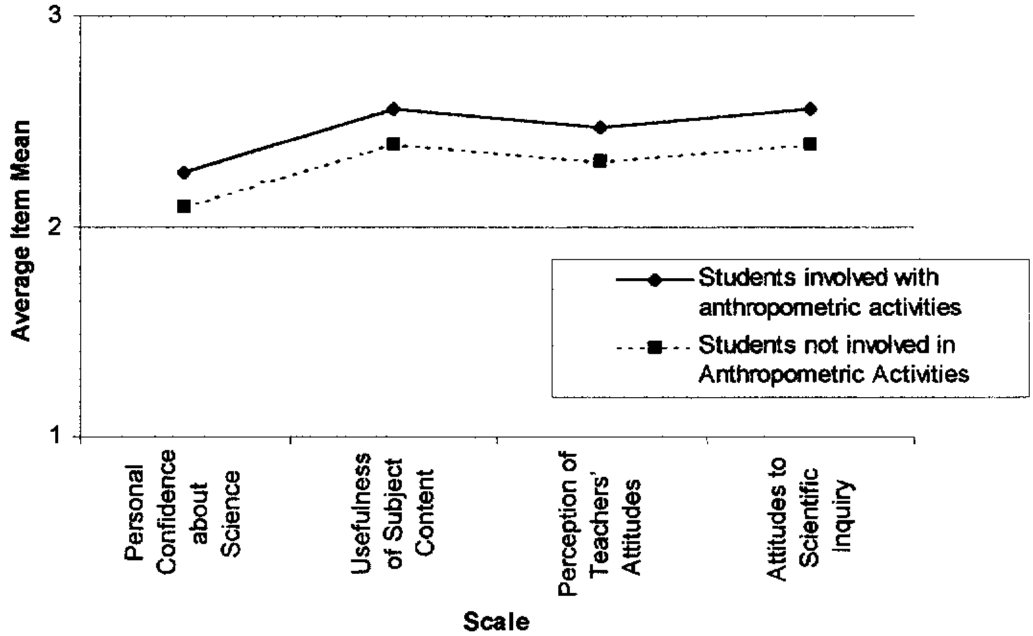

Figure 4.1 Differences in Students' Attitudes for Those Involved and Not Involved in Anthropometric Activities

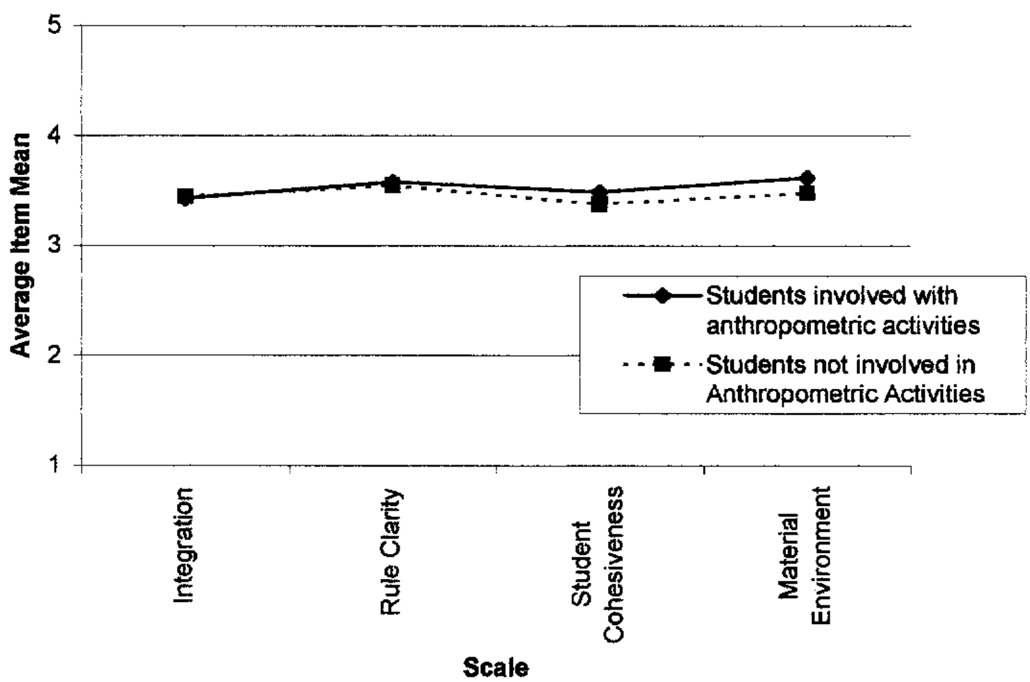

Figure 4.2 Differences in Students' Classroom Environment Perceptions for Those Involved and not Involved in Anthropometric Activities

4.4 Gender Differences

Research Aim 3 refers to investigating gender differences in students' perceptions of the classroom learning environment, attitudes to science and achievement.

Gender-related differences were explored for the achievement, attitude and environment measures by performing three multivariate analyses of variance (MANOVA) for repeated measures, with gender as the independent variable and the other variables as dependent variables. The first MANOVA involved achievement measures as dependent variables, the second MANOVA involved attitude variables, and the third MANOVA involved environment variables. Because the multivariate test yielded a statistically significant result using Wilks' lambda criterion in each case, a *t*-test for paired sample was conducted for each dependent variable.

The unit of statistical analysis chosen was the within-class gender subgroup mean obtained by calculating the males' mean and females' mean for each class. That is, each class provided a matched pair of means that enabled a fair comparison of genders.

This section is divided in three parts: subsection 4.4.1 deals with gender differences in achievement; subsection 4.4.2 reports gender differences in attitude measures; and subsection 4.4.3 refers to gender differences in learning environment perceptions.

4.4.1 Gender Differences in Achievement

Two sources of information were used to determine gender differences in academic achievement: Final Report Card grade in Biology (this refers to student final coursework grade in Biology) and Biology posttest score (this was done for comparative purposes to measure increase in achievement over the pretest). Performance on the anthropometric laboratory activity (specially designed for this research) was not used in gender analyses because of the small sample size (six classes). At the end of the 2000-2001 school year, I collected data on student final grades in biology, which were used as one of the measures of achievement. It refers to student performance grades on the mandated curricular content taught by all science teachers during the school year. The sample available for the Biology Report Card Grade and Biology posttest consisted of 25 pairs of within-class males' means and females' means (a total of 761 students).

Table 4.6 shows the average item mean, average item standard deviation, *t*-test result for differences between male and female students' responses to each of the two achievement measures, namely, the Biology Final Report Card Grade and Biology posttest score. Average item means were used to permit meaningful comparisons between scales when there are differences in the number of items in the different scales. The average item mean is obtained by dividing the scale mean by the number of items in that scale.

No statistically significant differences were found between males and females students in their achievement scores on either of the two measures. However, these results are different from those obtained by Zerega, Haertel, Tsai and Walberg (1986). Based on the

1976 National Assessment of Educational Progress (NAEP) and using a sample size of 3049 17-year old high school students, males scored higher on science achievement and motivation, and they perceived their classroom environments more positively than did females. They concluded that science was still viewed as a male domain: it is very important to be accepted by peers in high school and, because girls are not supposed to be good in science according to the stereotype, they confirm what peers expect.

4.4.2 Gender Differences in Attitudes

Table 4.6 also shows the average item mean and average item standard deviation for male and female students' responses to attitude to science scales. Also results for *t*-tests and effect sizes are shown. Table 4.6 is based on the same sample of 25 pairs of within-class gender means (761 students).

Table 4.6 shows that there is statistically significant ($p<0.05$) gender-related differences in students' attitude to science, with males showing a higher average item mean for Perception of Teachers' Attitudes and Attitudes to Scientific Inquiry; however, no significant gender differences were found for the scales of Personal Confidence about Science and Usefulness of Subject Content (Figure 4.3). These findings are in agreement with the 20-year meta-analysis by Weinburgh (1995), which revealed that boys have more positive attitudes to science than girls do. Other studies confirm similar findings (Catsambis, 1995). The effect sizes for Perception of Teachers' Attitude (0.45) and Attitude to Scientific Inquiry (0.56) are approximately half a standard deviation, suggesting sizeable gender differences for these two attitude scales (Table 4.6).

Table 4.6 Average Item Mean, Average Item Standard Deviation and Difference Between Males and Females (Effect size and *t*-Tests for Paired Samples) in Attitude to Science, Classroom Environment and Achievement Using the Within-Class Gender Mean as the Unit of Analysis

Scale	Average Item Mean		Average Item Standard Deviation		Difference Between Males and Females	
	Male	Female	Male	Female	Effect Size	*t*
Achievement						
Report Card Grade	2.53	2.63	0.63	0.71	0.15	-1.51
Biology Posttest	1.45	1.41	0.25	0.24	0.16	1.66
Attitudes to Science						
Personal Confidence about Science	2.10	2.18	0.33	0.28	0.26	-1.25
Usefulness of Subject Content	2.48	2.43	0.31	0.29	0.11	0.81
Perception of Teachers' Attitudes	2.44	2.27	0.39	0.37	0.45	4.09**
Attitudes to Scientific Inquiry	2.48	2.36	0.20	0.21	0.56	2.37*
Classroom Environment						
Integration	3.40	3.47	0.33	0.42	0.19	-0.97
Rule Clarity	3.48	3.61	0.43	0.44	0.30	-2.15*
Student Cohesiveness	3.30	3.47	0.44	0.42	0.40	-2.73*
Material Environment	3.47	3.55	0.38	0.48	0.19	-1.28

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

N= 396 Male students and 365 female students in 25 classes.

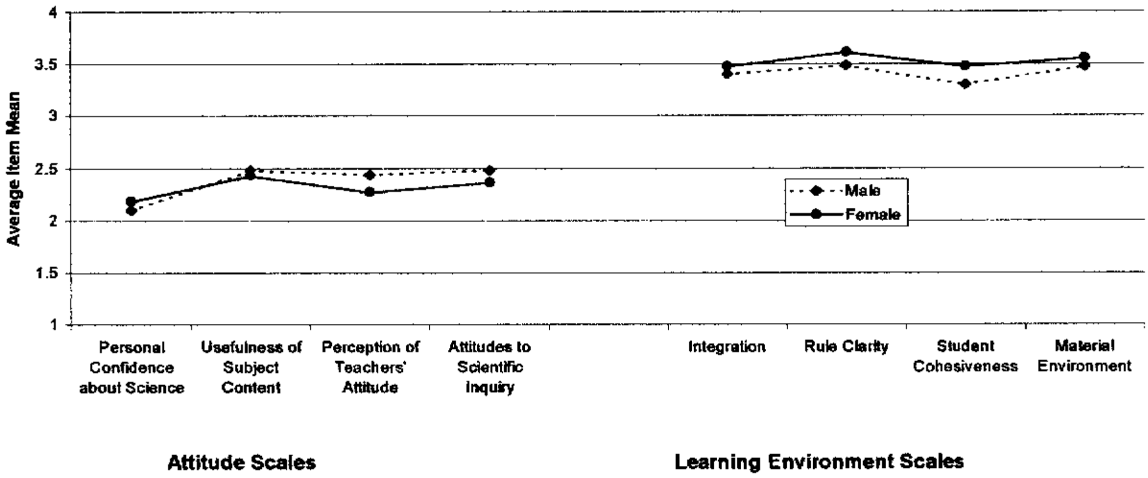

Figure 4.3 Average Item Mean for Male and Female Students' Attitudes to Science and Perceptions of Learning Environment

4.4.3 Gender Differences in Learning Environment Perceptions

Gender-related differences were also explored for the learning environment scales of the (SLEI), using multivariate analysis of variance (MANOVA) for repeated measures, with gender as the independent variable and the environmental scales as dependent variables. The within-class gender mean was again used as the unit of analysis. As the multivariate test was significant, *t*-tests for paired sample were performed for the individual SLEI scales and the results are reported in Table 4.6. The sample size again was 25 pairs of within-class gender means.

Table 4.6 reveals statistically significant ($p<0.05$) gender-related differences in students' perceptions of their learning environment, with females showing a higher average item mean for Rule Clarity and Student Cohesiveness. A graphical display of these differences is shown in Figure 4.3. Although statistically significant gender differences were not found for the scales Integration and Material Environment, still girls' scores were higher than boys' scores on these two scales. These findings support the results of others studies which reveal that females generally hold more favorable perceptions of their classroom environment than do males in the same classes (Fraser, Giddings, & McRobbie, 1995; Henderson, Fisher, & Fraser, 1998). The effect sizes for Rule Clarity (0.30) and Student Cohesiveness (0.40) are approximately one third of a standard deviation for within-class gender means, which confirms that the gender differences for these two classroom environmental scales are of a reasonable magnitude.

An interesting pattern is evident in Figure 4.3. Generally males have more favorable attitudes than females, but females have more favorable classroom environment perceptions than males.

4.5 Associations Between Students' Outcomes and their Classroom Environment Perceptions

Another goal of this research was to investigate associations between students' outcomes and their perceptions of the learning environment. Associations between students' perceptions of their classroom environment and student outcomes were investigated by the use of a series of simple correlation and multiple regression analyses using two units of analysis. These analyses were conducted and reported separately for attitude outcomes and achievement outcomes. The simple correlation (r) was used to describe the bivariate association between each attitudinal outcome and each SLEI scale. The standardized regression weight (β) was used to characterize the association between an attitudinal outcome and a particular learning environment scale when all other SLEI scales are mutually controlled. The sample size used for this analysis was 761 students in 25 classes. Analyses were performed separately for two units of analysis, namely, the student and the class mean.

Associations between attitudes and student perceptions of the learning environment are discussed in Section 4.5.1 and associations between achievement and learning environment are discussed in Section 4.5.2.

4.5.1 Associations Between Attitudes and Classroom Environment

Table 4.7 shows the results for associations between classroom environment and the four attitude scales. Generally, this table indicates that there are strong simple correlations between the four attitude scales and the four SLEI scales. The number of statistically significant simple correlations ($p<0.05$) is 15 out of 16 at the student level and 7 out of 16 at the class level. Furthermore, all statistically significant correlations are positive.

To reduce the Type I error associated with examining many simple correlations, a multiple regression analysis was conducted separately for each attitude scale to provide information about the joint influence of correlated environment scales on attitudes.

Table 4.7 Simple Correlation and Multiple Regression Analyses for Associations Between Student Attitudes and Classroom Dimensions for Two Units of Analysis

Scale	Unit of Analysis	Personal Confi- dence about Science		Useful- ness of Subject Con- tent		Perception of Teachers Attitudes		Attitudes to Scientific Inquiry	
		r	*β*	*r*	*β*	*r*	*β*	*r*	*β*
Integration	Individual	0.24**	0.29**	0.26**	0.31**	0.24**	0.17**	0.10**	0.07
	Class Mean	0.66**	0.91*	0.78**	0.94**	-0.27	-0.19	0.40*	-0.10*
Rule Clarity	Individual	0.17**	-0.32	0.18**	-0.03	0.21**	0.01	0.10**	0.06
	Class Mean	0.47*	-0.82	0.35	-0.54	0.81**	-0.15	-0.28	0.18
Student Cohesiveness	Individual	0.17**	0.09	0.17**	0.04	0.23**	0.16**	0.10**	0.07
	Class Mean	0.61**	-0.94*	0.28	0.41	0.85**	0.94**	-0.32	0.19
Material Environment	Individual	0.10**	-0.13*	0.12**	-0.10	0.16**	-0.06	0.04	-0.08
	Class Mean	0.39	-0.43	0.10	-0.32	0.38	0.28	-0.09	0.15
Multiple Correlation (*R*)	Individual		0.26**		0.27**		0.26**		0.12*
	Class Mean		0.79**		0.88**		0.92**		0.56

*$p<0.05$ **$p<0.01$
N= 761 students in 25 classes.

The bottom of Table 4.7 shows the multiple correlations (*R*) between each attitude scale and the set of four learning environment scales of the SLEI. Multiple correlations for different attitudes scales range from 0.12 to 0.27 and all are statistically significant with the student as the unit of analysis. With the class as the unit of analysis, the multiple correlation ranges from 0.56 to 0.92 and is statistically significant for all attitude scales except Attitudes to Scientific Inquiry.

In order to identify the individual classroom environment scales which contribute most to the variance in student attitudes, standardized regression coefficients (β) were examined (Table 4.7). When using the individual as the unit of analysis, Table 4 .7 indicates that Integration is a significant independent predictor of all attitudinal scales except Attitudes to Scientific Inquiry. Student Cohesiveness is a significant independent predictor of only one attitude scale, namely, Perception of Teachers' Attitudes. Material Environment is a significant independent predictor of Personal Confidence about Science; however, the beta value is negative, which indicates an inverse relationship. Rule Clarity is not a significant independent predictor of any attitudinal scale at the individual unit of analysis.

When using the class as the unit of analysis, Integration is a significant independent predictor of all attitudinal scales, except Perception of Teachers' Attitudes. Student Cohesiveness is a significant independent predictor of Personal Confidence and Perception of Teachers' Attitudes. Rule Clarity and Material Environment are not significant independent predictors of any of the attitudinal scales. As some regression coefficients are negative, however, it would be desirable to replicate the present research in future studies.

These results indicate that students' attitudes to science are most likely to be positive in classes where student perceive a strong integration between the concepts and principles covered in theory classes and in laboratory classes. These findings are consistent with results in other countries (Lee, 2001; McRobbie & Fraser, 1993). Student Cohesiveness and Rule Clarity also seem to be consistently related to students' attitudes.

4.5.2 Associations Between Achievement and Learning Environment

As reported in Table 4.8, simple correlation and multiple regression analyses were used to explore associations between achievement (Final Biology Report Card Grade, Biology posttest and anthropometric posttest) and the classroom environment dimensions of SLEI, using two units of analysis: the individual (perception scores of individual students) and the class mean (average of scores of all students within a class). The analyses are identical to those reported in Section 4.5.1 for attitude outcomes.

Different sample sizes were available for analyses involving associations between achievement and classroom environment. Biology report card scores were available for 662 students in 25 classes. A total of 598 students in 25 classes were present for the biology posttest, and 158 students in 6 classes were available for analyses involving the anthropometric activity. For anthropometric test, the sample size (N=6) was too small to generate dependable statistics for class means.

For the Final Report Grade in Biology, simple correlations were statistically significant ($p<0.05$) for the two SLEI scales of Integration and Student Cohesiveness (Table 4.8) at the student level of analysis. No significant correlations were found at the class level.

The simple correlation (r) for Biology posttest score was strong and statistically significant ($p<0.05$) for each of the four SLEI scales (Table 4.8) for both units of analysis. As expected, correlations were larger with class as the unit of analysis.

Table 4.8 Simple Correlation and Multiple Regression Analyses for Associations Between Student Achievement and Classroom Environment Dimensions for two Units of Analysis

Scale	Unit Analysis	Final Biology Report Card Grade		Biology Posttest Score		Anthropometric Posttest Score	
		r	β	r	β	*r*	β
Integration	Individual	0.09*	0.20**	0.24**	0.17**	0.11	-0.03
	Class Mean	0.11	0.77	0.45*	-0.40		
Rule Clarity	Individual	0.03	-0.09	0.22**	0.13	0.14	0.08
	Class Mean	-0.10	-1.69	0.55**	0.71		
Student Cohesiveness	Individual	0.08*	0.14*	0.17**	0.00	0.11	-0.03
	Class Mean	0.16	1.51**	0.53**	0.41		
Material Environment	Individual	-0.02	-0.19**	0.15**	0.06	0.17*	0.15
	Class Mean	-0.11	-0.56	0.49*	-0.20		
Multiple Correlation (*R*)	Individual		0.18**		0.25**		0.17
	Class Mean		0.75**		0.37		

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

N= 662 students in 25 classes for the biology report card score, 598 students in 25 classes for the biology posttest score and 158 students in 6 classes for the anthropometric score. For anthropometric test, the sample size (N=6) was too small to generate dependable statistics for class means.

The only statistically significant correlation (*r*) ($p<0.05$) for the anthropometric achievement test was with Material Environment (Table 4.8). This is understandable because this activity was purely a laboratory activity designed and implemented for this study and not part of the regular curriculum activities. Because only 158 students distributed among 6 classes took the anthropometric posttest, this number could have been too small to detect associations between anthropometric achievement and environment.

The bottom of Table 4.8 shows the multiple correlations (R) between SLEI scales and achievement measures. The multiple correlation values indicate that a statistically significant multiple correlation ($p<0.01$) existed between the set of dimensions of SLEI for both the Final Biology Report Card Grade and the Biology posttest when using the individual student as the unit of analysis (Table 4.8). However, when using the class means as a unit of analysis, the set of dimensions of the SLEI showed a statistically significant multiple correlation only with the Final Biology Report Card Grade. No significant multiple correlation was found between the set of SLEI scales and the scores on the anthropometric posttest. This could be partly due to the small sample size (158 students).

In order to identify the individual classroom environment scales which contribute to the variance in student achievement, standardized regression coefficient (β) were examined (Table 4.8). The standardized regression coefficients in Table 4.8 indicate that Integration, Student Cohesiveness and Material Environment are significant independent predictors of the Final Biology Report Card grade at the student level of analysis. Only Student Cohesiveness is a significant independent predictor of the Final Biology Report Card grade at the class level.

Integration is the only significantly independent predictor of the Biology posttest score when using the individual as the unit of analysis (Table 4.8). No significant independent predictors were found for the anthropometric posttest score for either unit of analysis.

These results suggest that integration of theoretical concepts with laboratory activities (Integration), a cohesive student group (Student Cohesiveness) and using appropriate laboratory materials and equipment (Material Environment) are likely to lead to improved student achievement. This finding replicates the results of previous studies (Fraser, Giddings & McRobbie, 1995; Lee, 2001; McRobbie & Fraser, 1993; Wong & Fraser, 1995).

Generally, I found stronger outcome-environment associations for attitudes (Table 4.7) than for achievement (Table 4.8). This finding is consistent with results from past research (Fraser, Giddings & McRobbie, 1995). Talton and Simpson (1986) also reported a stronger outcome-environment relationship for attitude toward science. They suggest that, by increasing teacher awareness to the important role that classroom environment might play in the formation of student attitudes toward science, it could be possible to substantially increase student interest and subsequently achievement in science.

4.6 Student Opinion about the Anthropometric Activities: Interview Results

One of the goals of my research was to evaluate the student-centered anthropometric activities in terms of students' opinions. Student feedback forms the basis for the qualitative part of the study. The qualitative data were collected mostly through written interviews. Students were provided with a list of written questions and they were asked to respond in writing. After I read their responses, if more in depth information was required or if clarification was needed, then an oral interview was carried out later. The oral interviews were recorded on audiotape and then transcribed. In order to optimize the credibility of interviews, as recommended by Erickson (1998), the transcriptions were shown to students, and revised subsequently based on their reactions. A copy of the interview questions is given in Appendix G.

Several authors and researchers in the field of science education are increasingly recommending combining quantitative and qualitative methods in the same study (Anderson, 1998; Erickson, 1998; Fraser & Tobin 1991; Lee 2001; Punch, 1998; Tobin & Fraser, 1998). The merits of this combination are discussed in chapter 2 (Literature Review) and chapter 3 (Methods).

The purposes of the interviews were twofold. First, I wanted to expand and gain clarification of some of the responses given on the attitude questionnaire and environment survey (quantitative portion of the study). Second, I wanted to assess how students viewed the anthropometric activities.

A group of 24 students (11 girls and 13 boys) was selected to participate in the interviews. These selected participants were honors students in the researcher's biology classes. These students were selected because they are more involved in classroom interactions, they are high achievers and they seem to have no problem in providing honest responses.

4.6.1 Interviews: A Mode of Clarifying Survey Results

The interviews shed important light on the information gathered from the quantitative part of the research. The interviews revealed that students felt that, at the end of any laboratory activity, it was difficult to write a conclusion stating what they had learned. They felt that they did not learn anything new. This is probably due to the fact that most laboratory activities are structured in a way to confirm topics or concepts discussed in non-laboratory classes. Students felt that these types of laboratory activities do not promote scientific inquiry; on the other hand, students felt that laboratory activities were excellent ways of integrating concepts learned in science classes and promoting cooperative group work. These could be the reasons why students involved in the anthropometric activities scored somewhat higher on some of the SLEI scales relative to other students (Figure 4.2).

Students were asked if they would like to be scientists. Four of the 11 girls (36%) interviewed said that they would like to be scientists. Some of the scientific careers mentioned were geneticist, forensic scientist, and doctor. Four of the 13 boys (31%) interviewed said that they would like to be scientists. However they were not specific about which scientific careers. One of the boys said that he would like to be a psychological scientist who helps people with their problems. Another boy said that it would really be fun to make a discovery. Another student said: "Yes, I would want to study a science that involves mathematics."

Students were asked about what science subjects they would like to take during the next two to three years in high school. The number of students who selected each subject is given in Table 4.9. Both boys and girls predominantly selected classes that are college-oriented courses, such as Chemistry, Physics, Advanced Placement Biology and Advanced Placement Chemistry.

Table 4.9 Number of Boys and Girls Who Would Like to Take Different High School Science Subjects

Gender	Number of Students Selecting a Subject						
	Chemistry	Physics	Advanced Placement Biology	Advanced Placement Chemistry	Marine Biology	Advanced Placement Environ-mental	Anatomy/ Physiology
Girls	9	6	7	8	4	3	4
Boys	13	12	10	10	3	1	5

The high number of students wanting to study science subjects at university is consistent with the positive attitudes found among the anthropometric group (Figure 4.1) relative to the other students.

4.6.2 Interviews: Providing Feedback on the Anthropometric Activities

Questions about the anthropometry laboratory activity were posed to the students. It was explained to them that the objective of the laboratory was to integrate principles and concepts in mathematics, technology and biology and that their comments would help me to improve the laboratory activity. Twenty-four students (11 girls and 13 boys) were interviewed. Their responses were separated by gender. Here is a summary of the questions and responses given by students.

Students were asked if they felt uncomfortable with any of the body measurements. The majority of the girls interviewed (9 out of 11 or 82%) did not feel uncomfortable with any of the measurements; however, two girls (2 out of 11 or 18%) said that they felt uncomfortable measuring their weights and hips and also sharing the information with the rest of the class.

The majority of the boys (12 out of 13 or 92%) interviewed did not feel uncomfortable with any of the measurements, although one boy (1 out of 13 or 8%) said that he felt uncomfortable about taking off his shoes to measure his foot size.

Students were asked if they had ever used a graphing calculator prior to this laboratory and if the instructions provided on how to use the calculator were easy to understand. Seven girls (7 out of 11or 64%) responded that they had never used a graphing calculator prior to this laboratory. Nine girls (9 out of 11 or 82%) stated that the instruction on how to use the calculator was very clear in its step-by-step format.

Three boys (3 out of 13 or 23%) stated that they had never used a graphing calculator before. Eleven boys (11 out of 13 or 85%) stated that the instructions provided on the use of the calculator were very clear.

Students were asked if they considered important the computation of the regression equations that showed the relationship between a person's height in relation to other body parts. Here are some of the responses given by the girls:

> Yes, I think that it was the most important part of the laboratory. It was almost the main goal of the entire laboratory.
>
> Yes, without these computations, I wouldn't have noticed the usefulness of anthropometric activities.

Here are some of the responses given by the boys:

> Yes, because you are able to predict height using regression equations.
>
> Yes, it taught me how to apply the measurement. We got to see real-world experience.

Students were asked about their positive perceptions of the laboratory activity. Some of the girls' responses were the following:

> I learned how to use a graphing calculator, and I also learned how to find patterns and how to find my height from other parts of the body.
>
> We learned how to calculate and use regression equations. It was fun to learn the relationship between body parts.

Some of the responses given by the boys were as follows:

> It was a very informative activity.
>
> We learned the relationship between human body parts.
>
> I had fun learning that our body parts are proportional.
>
> We learned and applied scientific and mathematics skills.

Most students, both boys and girls, agreed that the laboratory activity was interesting, but too long, as it took three days to gather and process the information.

Students were asked what were their positive perceptions and negative perceptions of cooperative learning groups. Some of the girls' responses were as follows:

> You get to share information and get input from one another and discuss your thoughts and answers; however, if your partner doesn't work, then you're stuck doing it yourself.
>
> Fun and you get to compare answers. However, sometimes you don't get your work done because you are constantly talking with the people in your group.
>
> Fun; you could work together if you are unsure about your answer; however you could get distracted easily.

Some of the responses given by the boys were as follows:

> Developing communication skills and learning how to share; however difference in personalities could lead to conflict.
>
> It is fun; however it gets loud.
>
> You can learn team relationships; however, fighting might happen.
>
> Improves interpersonal skills and saves time.
>
> You can do work faster; however people might disagree with one another on how to do things.

4.6.3 Summary of Interview Findings

A summary of the findings of the qualitative portion of the study reveals that both boys and girls believe that the anthropometric activity was a good learning activity (confirming positive attitude from the attitude survey; see Table 4.5). However it was considered too time-consuming. Students also agreed that the activity integrated science and mathematics skills and that they learned how to use the graphing calculator to develop regression equations. Cooperative learning activities are important, but conflict can arise. Both boys and girls agreed that Chemistry, Physics, Advanced Placement Biology and Advanced Placement Chemistry are the courses which they would like to take in the next two to three years in high school. Also girls were more specific when choosing the scientific career that they would like to pursue.

The interviews shed important light on the quantitative part of the research. Students felt that closed-ended laboratory activities do not promote scientific inquiry. On the other hand, the students felt that the laboratory activities provided excellent integration with concepts learned in science classes and also they promoted cooperative group work. One can hypothesize that these are some of the reasons why students who experienced the anthropometric activity scored somewhat more highly on the attitude and classroom environment scales than did the group of students who did not experience the anthropometric activity.

4.7 Chapter Summary

The findings from this study were reported in this chapter to answer the study's four research questions. The sample for most research questions consisted of 761 students in 25 classes. Also 24 students were interviewed.

The first research question involved the validity and reliability of the classroom environment questionnaire and the science attitude questionnaire. Item analyses supported the internal consistency reliability and ability to differentiate between classrooms for the four-scale classroom environment questionnaire. Analyses of attitude data supported the factorial validity, internal consistency reliability and discriminant validity of the four-scale attitude questionnaire.

The second research question involved evaluating the innovative anthropometric activities in terms of their impact on student outcomes (attitudes and achievement) and on the classroom learning environment. Sizeable effect sizes and statistically significant changes were found between pretest and posttest on two achievement measures. Also students using anthropometric activities showed higher scores on all four attitude to science scales and on one classroom environment scale survey when compared to students not using anthropometric activities. Interviews revealed that students considered the anthropometric activity a good learning activity, but that it probably should be broken down into various smaller activities.

The third research question focused on gender differences in attitudes, achievement and classroom environment perceptions. Whereas males reported more favorable attitudes than females, females perceived their classroom environment more favorably than males. No significant gender differences were found for the achievement measures. These findings in part support the results of others studies which reveal that females generally hold more favorable perceptions of their classroom environment than do males in the same classes (Fraser, Giddings, & McRobbie, 1995; Henderson, Fisher, & Fraser, 1998).

The fourth research question dealt with the associations between students' outcomes (achievement and attitudes) and their classroom environment perceptions. The simple correlation between the four attitude scales and the four classroom environment scales was statistically significant and positive for 15 out of 16 cases at the student level and for 7 out of 16 cases at the class level. The multiple correlation between each attitude scale and the set of four learning environment scales of the SLEI ranged from 0.12 to 0.27 and was statistically significant with the student as the unit of analysis for every attitude scale. With the class as the unit of analysis, the multiple correlations ranged from 0.56 to 0.92 and were statistically significant for all attitude scales except Attitudes to Inquiry. Integration was a particularly strong independent predictor of student attitudes.

Statistically significant simple correlations between achievement and environment were found for Final Biology Report Card Grade and Integration and Student Cohesiveness at the individual level of analysis, for all four SLEI scales for Biology posttest for both levels of analysis, and for Material Environment and the anthropometric test at the class level.

The multiple correlations between the SLEI scales and achievement measures were statistically significant for the Final Biology Report Card Grade at both levels of analysis and the Biology posttest when using the individual as the unit of analysis. Integration, Student Cohesiveness and Material Environment were significant independent predictors of the Final Biology Report Card grade at the student level of analysis, while only Student Cohesiveness was an independent predictor at the class level of analysis.

Integration was the only significant independent predictor of the Biology posttest score and this occurred when using the individual as the unit of analysis.

Overall, students' attitudes to science are most likely to be positive in classes where there is strong integration between the concepts and principles covered in theory classes and in laboratory classes (Integration), where students work well together (Cohesiveness), and where students are guided by formal rules (Rule Clarity). Student achievement appears to be higher in classes with more Integration and Student Cohesiveness and better Material Environment. Past research was replicated in that statistically significant associations were found between student outcomes (attitudes and achievement) and classroom environment (Fraser, Giddings & McRobbie, 1995; Lee, 2001; McRobbie & Fraser, 1993; Talton & Simpson 1986;Wong & Fraser, 1995).

In section 4.6, the results from interviews with 24 students yielded patterns consistent with the overall findings based on quantitative information (surveys involving 761 students). In particular, interview results were consistent with the questionnaire survey in suggesting that students who participated in the anthropometric activities demonstrated more positive attitudes to science and more positive perceptions of the learning environment than those who did not participated in the anthropometric activities. Therefore, overall, the quantitative and qualitative findings support the effectiveness of these anthropometric activities.

Chapter 5

CONCLUSIONS, IMPLICATIONS, AND LIMITATIONS

5.1 Introduction

As previously mentioned in Chapter 1 of this thesis, the study involved the evaluation of anthropometry activities for high school science. The four main goals of my research were:

1. To validate generally-applicable questionnaire for assessing classroom learning environments and attitudes to science among senior high school students in Southern Florida, USA.
2. To evaluate the student-centered anthropometric activities in terms of:
   (a) student achievement
   (b) student attitudes to science.
   (c) student perceptions of their classroom learning environment.
3. To investigate gender differences in students' achievement, attitudes and perceptions of classroom environment.
4. To investigate associations between the classroom learning environment and the student outcomes of achievement and attitudes.

This chapter is devoted to conclusions, discussion and implications of the present study. Also consideration is given to limitations and suggestions for future research.

These topics are covered under three sections. Section 5.2 summarizes the thesis; Section 5.3 reports the implications and limitations of the study and section 5.4 summarizes the major findings of the chapter.

5.2 Summary of the Thesis

The thesis is summarized under the following subheadings. Section 5.2.1 deals with the literature reviewed; Section 5.2.2 describes the research methods; Section 5.2.3 reports the validity and reliability of the environment and attitude survey instruments; Section 5.2.4 assesses the anthropometric activities in terms of student outcomes and learning environment; Section 5.2.5 focuses on gender differences in achievement, attitude and perceptions of the learning environment; Section 5.2.6 describes association between student outcomes and their classroom environment perceptions and Section 5.2.7 reports the interview results.

5.2.1 Summary of Literature Review Chapter

This chapter was devoted to reviewing literature that served as a foundation for gaining a better understanding of previous research relevant to my study. This included anthropometry, students' perceptions of classroom learning environment, students attitudes to science, gender differences in students' achievement and attitudes, and students' perceptions of learning environment, the use of mixed methods in educational research, and instruments for assessing classroom environment, and attitudes to science.

Literature dealing with anthropometry that was reviewed covered science process skills, such as collecting data, organizing and interpreting data, measuring, observing, predicting, reasoning and thinking, all of which have been used in the classroom activities involving human body measurement (anthropometry). The literature dealing with the use of anthropometric activities in the classroom served as foundation for developing the instructional materials that were used in the present study.

Also a historical review in the field of learning environments is provided. Starting with the conceptual framework laid out by Murray and Lewin, and the pioneering work of Walberg and Moos in developing two of the first learning environment scales.

Also research that established associations between students' perceptions of their learning environment and students' outcomes (attitudes and achievement) was reviewed. This line of research formed the fourth research question in my study.

Studies related to gender differences in the way in which students perceive their learning environment and in their attitudes to science were reviewed. Typically, females have been found to perceive more positive learning environments than their males counterparts in the same classrooms. My study's third research question focused on gender differences.

The literature that dealt with combining qualitative and quantitative research methods to answer the same research questions, including the importance of using mixed method was also reviewed.

A literature review of eight widely-applicable instruments for measuring students' perceptions of the learning environment (LEI, CES, ICEQ, CUCEI, QTI, CLES, WIHIC, and SLEI) for use at the high school and higher education levels was also conducted. Because the SLEI was selected for the present study, its initial development, validation and use in past studies was considered in detail.

Because one scale from the TOSRA (Test of Science Related Attitudes) was used in conjunction with the Modified Fennema-Sherman Attitude scales to gather information about students' attitudes to science in the present study, literature related to these instruments was discussed.

5.2.2 Summary of Research Method Chapter

This chapter described the research methods, sample sizes, procedures for collecting data, interviews, survey instruments, and how the data were analyzed.

Overall, the methods of the present study can be described as a mixture of quantitative and qualitative approaches. Different grain sizes were used to answer different research questions. Over 700 students responded, via survey, to the science attitude and learning classroom environment questionnaires. A sample almost this size also provided achievement data. However, the subgroup involved specifically in the anthropometric activities and achievement test was only 158 students. This represented the quantitative portion of the study. The qualitative data, gathered from 24 students' via interviews, were used to complement information provided in the surveys.

The survey instrument that was chosen to measure student attitudes towards science was based on selected items from the *Modified Fennema-Sherman Science Attitude Scales* (Doepken, Lawsky, & Padwa, 1993). The adapted version for this study consists of 24 items assessing the four scales of Personal Confidence about Science, Usefulness of the Subject Matter, Perception of Teacher's Attitudes and an Attitude to Scientific Inquiry.

Student perceptions of their classroom learning environment were measured using an adapted version of the personal form of the *Science Laboratory Environment Inventory* (SLEI) (Fraser, Giddings, & McRobbie, 1995; Fraser, McRobbie & Giddings, 1993). The version used in this study consists of four scales (Integration, Rule Clarity, Student Cohesiveness, and Material Environment), each containing six items.

Refinement and validation of the survey instruments were carried out by using item and factor analyses. Cronbach's alpha coefficient was used as a measure of each scale's internal consistency reliability. Factor analysis was used to check the structure or factorial validity of instruments. Also ANOVA was computed to determine whether the SLEI could differentiate between the perceptions of students in different classrooms.

The second research objective involved the evaluation of anthropometric activities in terms of achievement, attitudes and environment. For the cognitive portion of the study, three areas were considered: achievement scores on the anthropometric laboratory activity; a Biology achievement test; and the Final Report Card grade in Biology for the school year 2000-2001. A pretest-posttest design was used with the subsample of 158 students who experienced the anthropometric activities. Effect sizes (pre-post differences divided by the pooled standard deviation) and significance tests (MANOVA followed by t-tests for paired samples, were used to evaluate the teaching method in terms of changes in student achievement.

In order to measure the impact of using the anthropometric activities on students' attitudes and classroom environment, a comparison was made between students using anthropometric activities and students not using anthropometric activities. Again, effect sizes and significance tests (MANOVA followed by t-tests) were calculated.

Gender-related differences were explored for student achievement, attitudes and classroom environment using a series of multivariate analyses of variance (MANOVAs) for repeated measures, with gender as the independent variable and the other variables as dependent variables. Because the multivariate test yielded a statistically significant result using Wilks' lambda criterion in each case, a t-test for paired sample was conducted separately for each dependent variable. The within-class gender mean was used as the unit of statistical analysis because it reduces confounding by having each class yield a matched pair consisting of the male mean and the female mean for each scale.

And, lastly, associations between students' perceptions of their classroom environment and student outcomes (attitudes and achievement) were investigated by use of simple correlation and multiple regression analyses for two levels of analysis (the student and the class).

5.2.3 Validity and Reliability of Environment and Attitude Questionnaire

The first goal of the research was to validate the adapted versions of the Science Learning Environment Inventory (SLEI) survey and the Modified Fennema-Sherman Attitude Scales survey that were used in this research. Item analyses and factor analyses were used to validate and refine the survey instruments. The sample size for this analysis consisted of 761 biology students.

Reliability analysis was performed for the four scales and 24 items of SLEI using both the individual student and the class means as the units of analyses. In both cases, the alpha coefficients easily exceed the threshold of 0.60, which is often considered as acceptable for research purposes (Nunnally, 1967). An analysis of variance (ANOVA) was performed for each scale of the SLEI to assess each scale's ability to differentiate between the perceptions of students in different classrooms. The eta^2 statistics (which is the ratio of 'between' to 'total' sums of squares and represents the proportion of variance explained by class membership) was statistically significant ($p<0.01$) for each scale and ranged from 0.08 to 0.13 for different scales, suggesting that each scale of the SLEI was able to differentiate between students' perceptions in different classes. Although other authors have reported strong support for factor structure of the SLEI (Fraser, McRobbie

& Giddings, 1993; Lee, 2001), I was unable to replicate this structure with the present sample.

Reliability analysis was performed for the four scales and 22 items of Attitude Scale using both the individual student and the class as the units of analyses. The alpha coefficients for both units of analyses also exceeded the value of 0.60, which is considered as acceptable for research purposes.

The discriminant validity (mean correlation of a scale with other scales) ranged from 0.26 to 0.42 when using individual student as the unit of analysis and from 0.55 to 0.77 when using class mean as the unit of analysis, suggesting that each scale assessed a unique, although somewhat overlapping, dimension.

Principal components factor analysis with varimax rotation was used to examine the internal structure of the attitude item. Factor loading smaller than 0.40 were omitted from the analysis. A total of 761 biology students participated in the survey. For the Science Attitude Scales, 44% of the variance could be accounted for by the four interpretable factors, namely, Personal Confidence about Science, Usefulness of Subject Content, Perception of Teachers' Attitudes and Attitudes to Scientific Inquiry. However a closer analysis of the total variance showed that Personal Confidence About Science and Usefulness of Subject Content accounted for 11.44% and 13.13%, respectively, of the variance, while Perception of Teachers' Attitudes and Attitudes to Scientific Inquiry accounted for 9.40% and 9.91%, respectively, of the variance.

5.2.4. Evaluation of Anthropometric Activities in Terms of Achievement, Attitudes and Classroom Environment

The second goal of this research was to evaluate the student-centered anthropometric activities in terms of student performance, student attitudes to science and student perceptions of their classroom learning environment. A pretest/posttest design was used for the achievement portion of the study. Five hundred and ninety-eight (598) students took the biology test. However, analyses were restricted to the subsample of 158 students who had experienced the anthropometric laboratory activity.

In contrast to the pretest-posttest design used with achievement outcomes, only a single assessment of student attitudes and classroom environment was made. Therefore, it was more difficult to gauge the impact of using the anthropometric activities on students' attitudes and classroom environment. However, because a large sample had responded to the attitude and environment scales, it was possible to compare the attitudes and classroom environment scores of students undertaking the anthropometric activities (186 students) with a comparison group of students who were following the traditional curricular program (574 students).

Two sources of information were used to assess academic achievement: a Biology test and an anthropometric test. In order to measure changes in cognitive outcomes, a pretest and posttest design was implemented and subjected to *t*-test and effect sizes analysis, and multivariate analysis of variance (MANOVA).

The *t*-test for paired samples for differences between the pretest and posttest scores in Biology was statistically significant ($p<0.01$). The effect size was over three-quarters of a standard deviation (0.80) for the individual as the unit of analysis, which suggested a substantial difference between the pretest and posttest scores.

The anthropometry posttest score approximately doubled the pretest score. A *t*-test for paired samples for differences between the pretest and posttest scores in anthropometric was statistically significant ($p<0.01$). The effect size of 1.08 for the individual as the unit of analysis also suggests a substantial difference between the pretest and posttest scores.

When students who did not participate in the anthropometric activities were compared to students who participated in the anthropometric activities, the anthropometric group showed higher scores for all four scales of the attitudes to science survey, namely, Personal Confidence about Science, Usefulness of Subject Content, Perception of Teachers' Attitudes and Attitudes to Scientific Inquiry. The effect sizes for the four attitude scales were approximately one fifth of a standard deviation (0.22), suggesting modest attitudinal differences between students who participated in the anthropometric activities and those who did not.

In terms of students' perceptions of the science laboratory environment, only the Material Environment scale, showed a statistically significant ($p<0.05$) difference between the two groups of students (those who were involved in anthropometric activity and those who were not involved).

Overall, these results support the positive influence of using anthropometric activities on both students' achievement and attitudes and their classroom learning environment.

5.2.5 Gender Differences in Achievement, Attitude and Perceptions of the Learning Environment

The third goal of this study was to investigate gender differences in students' achievement, attitudes and perceptions of classroom environment. Gender-related differences were first explored for the achievement and attitude measures by the use of multivariate analysis of variance (MANOVA) for repeated measures, with gender as the independent variable and the other variables as dependent variables. The unit of statistical analysis chosen was the within-class gender subgroup mean obtained by calculating the males' mean and the females' mean for each class. That is, each class provided a matched pair of means that enabled a fair comparison of genders.

Three sources of information were used to determine gender differences in academic achievement: Final Report Card grade in biology (this refers to student final coursework grade in Biology), Biology achievement test, and the score for the anthropometric laboratory activity at the posttest stage. The sample size was 760 students (396 males and 364 females) distributed among 25 classes. No statistically significant differences were found between male and females students in their achievement scores on any of the three measures. However, statistically significant (p<0.05) gender-related differences in student's attitude to science were found, with males showing a higher average item mean for Perception of Teachers' Attitudes and Attitudes to Scientific Inquiry. The effect sizes for Perception of Teachers' Attitude and Attitude to Scientific Inquiry were approximately half a standard deviation, suggesting sizeable gender differences for these two attitude scales.

Gender-related differences were also explored for the learning environment scales of the (SLEI), using multivariate analysis of variance (MANOVA) for repeated measures, with gender as the independent variable and the other variables as dependent variables.

Statistically significant ($p<0.05$) gender-related differences in students' perceptions of their learning environment was found, with females showing a higher average item mean for Rule Clarity and Student Cohesiveness. These findings in part support the results of others studies which reveal that females generally hold more favorable perceptions of their classroom environment than do males in the same classes (Fraser, Giddings, & McRobbie, 1995; Henderson, Fisher, & Fraser, 1998). The effect sizes for Rule Clarity and Student Cohesiveness were approximately one third of a standard deviation, suggesting that gender differences for these two classroom environmental scales are of a reasonable magnitude.

These findings that boys have more positive attitudes to science than girls is in agreement with past studies (Catsambis, 1995; Weinburgh 1995). Based on these findings one may conclude that females students demonstrated more favorable perceptions of the learning environment than males, primarily with Student Cohesiveness and Rule Clarity.

5.2.6 Associations Between Students' Outcomes and their Classroom Environment Perceptions

Another goal of this research was to investigate associations between students' outcomes and their perceptions of the learning environment.

Associations between students' perceptions of their classroom environment and student attitudes were investigated by the use of simple correlation and multiple regression analyses using two units of analysis (individual and class mean).

With only one exception, all four attitudinal scales, namely, Personal Confidence about Science, Usefulness of Subject Content, Perception of Teachers Attitudes and Attitudes to Scientific Inquiry, showed significant simple correlations at the student level for all four scales of SLEI, namely, Integration, Rule Clarity, Student Cohesiveness and Material Environment.

The multiple correlation values indicate that a statistically significant multiple correlation (p<0.05) existed among four attitude scales and the set of four environment scales when using the individual student as the unit of analysis. The lowest multiple correlation of 0.12 was for Attitude to Scientific Inquiry. When using the class as the unit of analysis, the multiple correlations have larger magnitudes, and they are statistically significant for all attitude scales except Attitudes to Scientific Inquiry.

At the student level, Integration is a significant independent predictor of all attitudinal scales except Attitudes to Scientific Inquiry. When using the class as the unit of analysis, Integration is also a significant independent predictor of all attitudinal scales, except Perception of Teachers' Attitudes. These results indicate that students' attitudes to science are most likely to be positive in laboratory classes where student perceive a strong integration between the concepts and principles covered in theory classes and in laboratory classes. These findings are consistent with results in other countries (Lee, 2001; McRobbie & Fraser, 1993).

Simple correlation and multiple regression analyses were used to explore associations between achievement (Final Biology Report Card Grade, Biology posttest and anthropometric posttest) and the classroom environment dimensions of SLEI, using two units of analysis: the individual (perception scores of individual students) and the class mean (average of scores of all students within a class).

For the Final Report Grade in biology, simple correlations were statistically significant ($p<0.05$) for the two SLEI scales of Integration and Student Cohesiveness at the student level of analysis.

The simple correlation values for Biology posttest scores show a strong statistically significant ($p<0.05$) correlation with each of the four SLEI scales for both units of analysis.

The only statistically significant correlation ($p<0.05$) for the anthropometric achievement test was with Material Environment. This is understandable; because this activity was purely a laboratory activity designed and implemented for this study and not part of the regular curriculum activities.

Multiple correlations (R) between SLEI scales and achievement measures were also explored. The multiple correlation values indicated that a statistically significant multiple correlation ($p<0.01$) existed between the set of dimensions of SLEI and both the Final Biology Report Card Grade and the Biology posttest when using the individual student as the unit of analysis. However, when using the class means as a unit of analysis, the set of dimensions of the SLEI showed a statistically significant multiple correlation only with the Final Biology Report Card Grade.

In order to identify the individual classroom environment scales, which contribute to the variance in student achievement, standardized regression coefficient, were examined. The standardized regression coefficients indicate that Integration, Student Cohesiveness and Material Environment are significant independent predictors of the Final Biology Report Card grade at the student level of analysis. Rule Clarity and Student Cohesiveness are significant independent predictors of the Final Biology Report Card grade at the class level.

Integration is the only significantly independent predictor of the Biology posttest score when using the individual as the unit of analysis.

These results suggest that integration of theoretical concepts with laboratory activities (Integration), a cohesive student group (Student Cohesiveness) and using appropriate laboratory materials and equipment (Material Environment) are likely to lead to student achievement. This finding replicates the results of previous studies (Fraser, Giddings & McRobbie, 1995; Lee, 2001; McRobbie & Fraser, 1993; Wong & Fraser, 1995).

I found stronger outcome-environment associations for attitudes than for achievement. This finding is consistent with results from past research (Fraser, Giddings & McRobbie, 1995). Talton and Simpson (1986) also reported similar findings. They found that classroom environment had the strongest relationship with attitude toward science.

5.2.7 Students Interview Results on the Anthropometric Activities

One of the key components of this research was to evaluate student-centered anthropometric activities in terms of student's feedback. Students' interviews form the basis for the qualitative part of the study. A group of 24 students (11 girls and 13 boys) was selected to participate in the interviews.

The qualitative data were collected mostly through written interviews. Students were provided with a list of written questions and they were asked to respond in writing. After reading their responses, if more in depth information was required or if clarification was needed, then an oral interview was carried out. The oral interview was recorded on audiotape and then transcribed. In order to optimize the credibility of interviews, as recommended by Erickson (1998), the transcriptions were shown to students and subsequently revised. The purposes of the interviews were twofold. First, I wanted to expand and gain clarification of some of the responses given on the attitude questionnaire and environment survey (quantitative portion of the study). Second, I wanted to assess how students viewed the anthropometric activities.

The interviews shed important light on information gathered from the quantitative part of the research. The interviews revealed that students felt that, at the end of any laboratory activity, it was difficult to write a conclusion stating what they had learned. They felt that they did not learn anything new. This is probably due to the fact that most laboratory activities are structured in a way to confirm topics or concepts discussed in non-laboratory classes. Students felt that these types of laboratory activities do not promote scientific inquiry; however, on the other hand, the students felt that these laboratory activities were excellent ways of integrating concepts learned in science classes and promoting cooperative group work.

A summary of the findings of the qualitative portion of the study revealed that both boys and girls believe that the anthropometric activity was a good learning activity (their positive attitudes confirm the findings from the attitude survey); however, it was considered too time-consuming. Students also agreed that the activity integrated science and mathematics skills and that they learned how to use the graphing calculator to develop regression equations. Students also stated that cooperative learning activities are important but conflict can arise.

Generally, the findings based on the qualitative information were consistent with patterns emerging from the quantitative information, and they support the effectiveness of the anthropometric activities.

5.3 Limitations, Implications and Significance of the Study

This section describes the limitations of the present study (Section 5.3.1), and suggestions for future studies (Section 5.3.2).

5.3.1 Limitations of the Study

One of the ways to measure the quality of instruction at a given school is by looking at students' performance on standardized tests. The Florida Comprehensive Assessment Test (FCAT) is a statewide assessment designed to measure students' skills in writing, reading, and mathematics. At the school where this research was conducted, the academic achievement level is much higher than the district average. For Grade 10 students undertaking the standard curriculum (728 students), 55% scored 3 and above (maximum score is 5) on the FCAT reading test while, at the district level, only 26% scored 3 and above. On the mathematics portion of the FCAT test, 81% of the students scored 3 and above while, at the district level, only 54% scored 3 or higher. The school is located in a suburban area that serves a diverse community, both culturally and socio-economically. Although the student membership in Region V where the school is located is reported as 23% white, 11% black, 64% Hispanic and 2% others, the ethnic composition at the researcher's school is, 55% white, 16.5% black, 23.4% Hispanic and 5% others (school year 2001).

Because the demographic make-up and academic achievement level of the school where this research was undertaken do not reflect the same parameters as the district, findings from my study cannot be generalized to the whole district. Therefore, it would be desirable to replicate the present study with other samples in future research. Other limitation related to the present study is the sample size. In my study, the sample represents 23% of the school population (3,200 students) and only 4% of the district Grade 10 students (19,161 students). The sample is limited in terms of the area in which the school is located and therefore cannot be representative of all Grade 10 high school students in the district.

Also the sample size of those students undertaken the anthropometric activities was very small (under 200) and was conducted as a pilot study only in the researcher's classes.

The lack of a pre and post design for the attitude and environment survey may also be consider as a limitation of the present study.

Therefore the results of this study should be interpreted and generalized with caution.

5.3.2 Implications for Future Studies

An important suggestion for future studies on the use of anthropometric activities associated with learning environment and attitudes to science, would be to conduct a more comprehensive study of a larger sample size and at different schools with ethnic composition, achievement level, and socio-economic status that closely resemble the whole school district.

In the present study, some regression coefficients and simple correlations between the attitude scales and the environment scales (SLEI) were negative. Therefore, it would be desirable to replicate the present research in future studies.

In the present study, the qualitative component was based solely on students' interviews. For future research I suggest that additional qualitative methods of inquiry be used, such as narrative, case studies or ethnographical studies. Anderson and Arsenault (1998) stated that "a fundamental assumption of the qualitative research paradigm is that a profound understanding of the world can be gained through conversation and observation in natural settings rather than through experimental manipulation under artificial conditions" (p. 119).

5.4 Summary of the Chapter

Firstly, in reference to the survey instruments, we may conclude that item analyses supported the internal consistency reliability and ability to differentiate between classrooms of the learning environment questionnaire and the analyses of attitude data supported the factorial validity, internal consistency reliability and discriminant validity of the attitude questionnaire.

Secondly, based on the use of anthropometric activities in the classroom, one may conclude that there was a positive influence of using anthropometric activities on both students' attitudes and their perceptions of the classroom learning environment. The findings based on qualitative information (interviews, which involved twenty-four students) were consistent with patterns emerging from our quantitative information (surveys, which involved 760 students) and they supported the effectiveness of the anthropometric activities.

Thirdly, I investigated gender differences in students' achievement, attitudes and perceptions of classroom environment. These findings revealed that boys have more positive attitudes to science than girls do and are in agreement with past studies (Catsambis, 1995; Weinburgh 1995). On the other hand, females' students demonstrated more favorable perceptions of the learning environment than males, primarily with Student Cohesiveness and Rule Clarity.

Fourthly, associations between students' outcomes and their perceptions of the learning environment were investigated. The association between student attitudes and their perception of the learning environment indicated that students' attitudes to science are most likely to be positive in laboratory classes where student perceive a strong integration between the concepts and principles covered in theory classes and in laboratory classes.

These findings are consistent with results in other countries (Lee, 2001; McRobbie & Fraser, 1993).

The association between achievement and student perceptions of their learning environment, suggest that integration of theoretical concepts with laboratory activities (Integration), a cohesive student group (Student Cohesiveness) and using appropriate laboratory materials and equipment (Material Environment) are likely to lead to student achievement. This finding replicates the results of previous studies (Fraser, Giddings & McRobbie, 1995; Lee, 2001; McRobbie & Fraser, 1993; Wong & Fraser, 1995).

I found stronger outcome-environment associations for attitudes than for achievement. This finding is consistent with results from past research (Fraser, Giddings & McRobbie, 1995). Talton and Simpson (1986) also reported similar findings

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APPENDIX A

SURVEY INTRUMENTS
(SCIENCE LABORATORY ENVIRONMENT INVENTORY (SLEI))
(FENNEMA-SHERMAN ATTITUDE SCALE)

STUDENTS ATTITUDE TOWARDS SCIENCE AND THEIR PERCEPTIONS OF SCIENCE LABORATORY ENVIRONMENT

By Millard Lightburn

DIRECTIONS
This survey contains questions about your thoughts about science and your perception about the science laboratory. **Part A** refers to student attitude toward science (questions 1-24) and **Part B** refers to student perception of laboratory environment (Questions 25-48).

I. Part A : Students Attitude towards Science (questions 1-24)

There are no ***right*** or ***wrong*** answers. The only correct responses are those that are true for you. Whenever possible, let the things that have happened to you help you make a choice. Your opinion is greatly appreciated.

Although some statements in this survey are fairly similar to other statements, you are asked to indicate your opinion about all statements.
All answers should be bubbled in on the scantron sheet. Please do not write on this booklet.

Example 1: Suppose that you were given the statement: "I like science". You would need to decide whether you **Strongly Agree, Agree, Not Sure, Disagree or Strongly Disagree**. For example, if you selected **Strongly Agree**, you would bubble in **A (see page 2)**.

II. Part B: Perception of Science Laboatory Environment (questions 25-48)

Example 2: Suppose that you were given the statement "I'm required to follow certain rules in the laboratory". You would need to decide whether this event, **Almost Never** happens, **Seldom** happens, happens **Sometimes**, happens **Often** or happens **Very Often.** For Example, if you selected that the event happens **Sometimes,** you would bubble in **C (see page 3).**

Don't forget to write your name, gender, grade level, birthdate and ID number.

Under Special Code please fill in the following information:
-Under Letter K indicate the code for your science teacher's name: Bubble **0** for Mr. Bullock; **1** for Ms. Evans; **2** for Mr.Lightburn; **3** for Ms. Magnus; **4** for Ms. McCarthy; **5** for Mr. Pagani; and **6** for Ms. Valois.

I. PART A: SCIENCE ATTITUDE SURVEY

Use the following key to bubble in your response for questions 1-24:
-If you **Strongly Agree** with the statement bubble in **A**.
-If you **Agree** with the statement bubble in **B**.
-If you are **Not Sure or You can't answer** the statement bubble in **C**.
-If you **Disagree** with the statement bubble in **D**.
-If you **Strongly Disagree** with the statement bubble in **E**.

	Strongly Agree (A)	Agree (B)	Not Sure (C)	Dis-Agree (D)	Strongly Disagree (E)
1. I am sure that I can learn science.	A	B	C	D	E
2. Science is a worthwhile, necessary subject.	A	B	C	D	E
3. My teachers have been interested in my progress in science.	A	B	C	D	E
4. I would prefer to find out why something happens by doing an experiment than by being told.	A	B	C	D	E
5. I know I can do well in science.	A	B	C	D	E
6. I'll need a good understanding of science for my future work.	A	B	C	D	E
7. My teachers have encouraged me to study more science.	A	B	C	D	E
8. I would prefer to do my own experiments than to find out information from the teacher.	A	B	C	D	E
9. I am sure I can do advanced work in science.	A	B	C	D	E
10. I study science because I know how useful it is.	A	B	C	D	E
11. My teachers think I'm the kind of person who could do well in science.	A	B	C	D	E
12. I would prefer to do an experiment on a topic than to read about it in science magazines.	A	B	C	D	E
13. Science is hard for me.	A	B	C	D	E
14. I don't expect to use much science when I get out of school.	A	B	C	D	E
15. Getting a teacher to take me seriously in science is a problem.	A	B	C	D	E
16. I would rather agree with other people than to do an experiment to find out myself.	A	B	C	D	E
17. I don't think I could do advanced science.	A	B	C	D	E
18. Taking science classes is a waste of time.	A	B	C	D	E
19. I have a hard time getting teachers to talk seriously with me about science.	A	B	C	D	E
20. I would rather find out about things by asking an expert than by doing an experiment.	A	B	C	D	E
21. Most subjects I can handle OK, but I just can't do a good job with science.	A	B	C	D	E
22. Doing well in science is not important for my future.	A	B	C	D	E

23. My teachers would not take me seriously if I told them I was interested in a career in science and mathematics.	A	B	C	D	E
24. It is better to be told scientific facts than to find them out from experiments.	A	B	C	D	E

II. Part B: PERCEPTION OF SCIENCE LABORATORY ENVIRONMENT

For questions 25-48 use the following key to bubble in your response:

-If the event **Almost Never** happens, then bubble in **A**.
-If the event **Seldom** happens, then bubble in **B**.
-If the event happens **Sometimes**, then bubble in **C**.
-If the event happens **Often,** then bubble in **D**.
-If the event happens **Very Often**, then bubble in **E**.

	Almost Never (A)	Seldom (B)	Some-times (C)	Often (D)	Very Often (E)
25. My regular science class work is integrated with laboratory activities.	A	B	C	D	E
26. My laboratory class has clear rules to guide my activities.	A	B	C	D	E
27. I get along with students in this laboratory class.	A	B	C	D	E
28. I find that the laboratory is crowded when I am doing experiments.	A	B	C	D	E
29. I use the theory from my regular science class sessions during laboratory activities.	A	B	C	D	E
30. I'm required to follow certain rules in the laboratory.	A	B	C	D	E
31. Members of this laboratory class help me.	A	B	C	D	E
32. The equipment and materials that I need for laboratory activities are readily available.	A	B	C	D	E
33. The topics covered in regular science class work are quite different from topics with which I deal in laboratory sessions.	A	B	C	D	E
34. There is a recognized way for me to do things safely in this laboratory.	A	B	C	D	E
35. I get to know students in this laboratory class well.	A	B	C	D	E
36. I am ashamed of the appearance of this laboratory.	A	B	C	D	E
37..What I do in laboratory sessions help me to understand the theory covered in science class.	A	B	C	D	E
38. The teacher outlines safety precautions to me before laboratory sessions begin.	A	B	C	D	E
39. I am able to depend on other students for help during laboratory classes.	A	B	C	D	E
40. The laboratory equipment which I use is in poor working order.	A	B	C	D	E
41. What I do in our regular science class is unrelated to my laboratory work.	A	B	C	D	E

42. There are few fixed rules for me to follow in laboratory sessions.	A	B	C	D	E
43. I work cooperatively in laboratory sessions.	A	B	C	D	E
44. The laboratory is an attractive place for me to work in.	A	B	C	D	E
45. My laboratory work and regular science class work are unrelated.	A	B	C	D	E
46. My laboratory class is rather informal and few rules are imposed on me.	A	B	C	D	E
47. I have little chance to get to know other students in this laboratory class.	A	B	C	D	E
48. My laboratory has enough room for individual or group work.	A	B	C	D	E

III. PART C: GENERAL INFORMATION

49. Choose the ethnic/racial group that best describes you:
    a) White b) Hispanic c) Black (Non Hispanic) d) Asian
    e) Others

50. Please specify what Biology course you are currently enrolled in:
    a) Regular b) Honors c) Gifted d) Advanced Placement (AP)

SCALE ALLOCATION AND SCORING DIRECTIONS FOR EACH QUESTION

Science Attitude Scales				Science Environment Scales			
Personal Confidence about Science	**Usefulness of Subject Content**	**Perception of Teachers Attitudes**	**Attitudes to Scientific Inquiry**	**Integration**	**Rule Clarity**	**Student Cohesive-ness**	**Material Environ-ment**
1 (+)	2 (+)	3 (+)	4 (+)	25 (+)	26 (+)	27 (+)	28 (-)
5 (+)	6 (+)	7 (+)	8 (+)	29 (+)	30 (+)	31 (+)	32 (+)
9 (+)	10 (+)	11 (+)	12 (+)	33 (-)	34 (+)	35 (+)	36 (-)
13 (-)	14 (-)	15 (-)	16 (-)	37 (+)	38 (+)	39 (+)	40 (-)
17 (-)	18 (-)	19 (-)	20 (-)	41 (-)	42 (-)	43 (+)	44 (+)
21 (-)	22 (-)	23 (-)	24 (-)	45 (-)	46 (-)	47 (-)	48 (+)

Scoring Directions:
Each positive question receives a score based on the following points system:
A = 5 B = 4 C = 3 D = 2 E = 1
The scoring for each negative question should be reversed:
A = 1 B = 2 C = 3 D = 4 E = 5

Add the scores for each category to get the total for that group. The highest possible score for each group of statements is 30 points.

APPENDIX B

ANTHROPOMETRY LABORATORY GUIDE

LABORATORY: ANTHROPOMETRY (HUMAN BODY MEASUREMENTS)

Developed by: Millard E. Lightburn
Biology Teacher

Name:________________________________No._______Date__________Period______

Objective: Gain experience in linear measurements and data analysis.

Materials:

-Metric ruler	-string
-Scale	-graphing calculator

Procedure:

1. Using the string, take different measurements of your body as indicated in Table 1 and Table 2. After each measurement has been completed, place the string on the meter stick and determine its length in centimeter (round to the nearest tenth).
2. Record the measurements in Table 1 and Table 2.
3. Students will share some of their data with the rest of the class. This information will be grouped by gender and subsequently used for statistical analysis (Record in Tables 3 & 4).
4. Complete the graph information.

General Information

Age _______	Weight (in Kg)_______	Gender ____	DOB_________
(As of today's date)	(Divide weight in lbs. by 2.204)		(Date of birth)

Table No. 1: CIRCUMFERENCE MEASUREMENTS
(In centimeters to the nearest tenth)

1. Circumference of head (measured at eyebrow level)..............___________cm.
2. Circumference of neck (measured at midpoint of neck) ... ___________cm
3. Circumference of waist (at the level of umbilicus (navel))...... ___________cm
4. Circumference of right wrist (above ulna styloid process)........ __________ cm
5. Circumference of left wrist (above ulna styloid process) ....___________cm
6. Circumference of right ring finger ....___________ cm
   (At proximal phalanx, where ring is worn on fourth finger of right hand).
7. Circumference of left ring finger ....___________ cm
8. Circumference of right calf.......................................___________ cm
   (Measure maximum circumference of posterior protrusion of the calf; calf relaxed)
9. Circumference of left calf...___________cm
10. Circumference of hip (pelvis width; to be measured at home)____________cm

Table No. 2 LINEAR MEASUREMENTS (in centimeters to nearest tenth)

1. Height.._______cm
(Remove shoes and stand against the meter sticks; hold a ruler level so it touches the top of the student's head. Read the height from the underside of the ruler).
2. Arm span ....________cm.
(Extend both arms against the wall; measure from tip of right middle finger to tip of left middle finger).
3. Right upper arm ....________cm
(Measure inner distance from bend of elbow to the top of the humerus)
4. Left upper arm ...._________cm.
5. Right lower arm (forearm).._________ cm.
(Measure inner distance from bend of wrist to bend of elbow)
6. Left lower arm (forearm)..________cm.
7. Right lower leg ....________cm.
(Measure from the center of the patella (kneecap) to the ankle (bend of foot).
8. Left lower leg ...._________cm.
9. Right upper leg (measure from center of patella to the top of femur)...________cm.
10. Left upper leg ...._________cm.
11. Hand span ...._________cm.
(Extend hand; place hand on ruler, measure from tip of thumb to tip of pinkie, exclude fingernails)
12. Right hand size ...._______cm.
(Palm face up, measure from bend of wrist to tip of middle finger; see figure)
13. Left hand size ....________ cm
14. Distance from knee to floor..________cm.
(**You must be seated and shoeless;** measure from center of the patella to the floor)
15. Length of each finger on left hand (measure length of each phalanx; see figure)
Thumb______ Index_______ Middle_______ Ring _______ Pinkie_________.
16. Length of each finger on right hand ....:
Thumb______ Index_______ Middle_______ Ring _______ Pinkie_________.
17. Length of right foot (make outline of foot; measure from heel to tip of longest toe)..______cm.
18. Length of left foot ....______cm.
19. Right foot breadth ....______cm
(Measure maximum width of right foot; see figure, draw outline of barefoot at home)
20. Left foot breadth ...(draw outline of left foot at home; measure width).________cm.

ANALYSIS AND OBSERVATIONS

A. Construct a single bar graph and include each pair of the measurements listed below. Make certain that the members of each pair are graphed side by side. Place centimeters on the y-axis.
   1. Circumference of neck and circumference of waist.
   2. Length of right lower arm and length of right foot.
   3. Length of left lower arm and length of left foot.
   4. Circumference of head and distance from knee to floor.
   5. Your height and your arm span
   6. Circumference of right calf and circumference of neck.

B. Compare the above graphed measurements and explain if there are any relationships among the graphed pairs.

C. Compare your height to the following measurements
   (Divide height by each of the measurements listed below)

   1. My height is _________ times the length of my right foot (divide height by foot length).
   2. My height is _________ times the length of my right forearm (divide height by forearm)
   3. My height is _________ times the length of my right upper arm (divide height by right upper arm).
   4. My height is _________ times the length of my right upper leg (divide height by right upper leg).
   5. My height is _________ times the length of my right lower leg (divide height by right lower leg).
   6. My height is _________ times the circumference of my head (divide height by circumference of head).

D. Gather length measurement data from your classmates. Record information for males in Table No. 3 and for females in Table No. 4.

E. Use your graphing calculator to graph and calculate regression equation of the relationship among the following variables by **gender**: (Use information from Tables No. 3 and 4 to compute equations **a** through **f**).
   (Your teacher will assist you with the graphing calculator).
   List the regression equation (y = ax + b), the slope (a), y-intercept (b) and regression coefficient (r).

   a. Height (y) versus length of right forearm (x).
      Y= ______________________________ a = ________ b= _____ r = ______

b. Height (y) versus length of right upper arm (x).
Y=____________________ a = _______ b= __________ r = _______

c. Height (y) versus length of right upper leg (x).
Y=____________________ a = _______ b= __________ r = _______

d. Height (y) versus length of right lower leg (x).
Y=____________________ a = _______ b= __________ r = _______

e. Height (y) versus arm span (x).
Y=____________________ a = _______ b= __________ r = _______

f. Height (y) versus length of right foot (x).
Y=____________________ a = _______ b= __________ r = _______

DISCUSSION AND CONCLUSION

1. At a crime scene, a shoe print measuring 25-cm was found. Estimate the approximate height of the crime suspect. Explain your answer and show work. (Use equation **f** from part **E**).

2. If the length of the forearm bone is used to determine a person's height, what would be the independent variable? What would be the dependent variable? Explain

3. Some people believe that your arm span is always equal to your height. Based on the results of this laboratory (use data for the whole class from Table No. 6), would this statement be true or false? Explain your answer in terms of numbers and percentages. Use the terms **Square, Wide Rectangle** and **Tall Rectangle.** (If the difference between your arm span and height is equal or less than **2 cm, you are considered a Square.** If your arm span is greater than your height by **more than 2 cm, you are considered a Wide Rectangle.** If your height is greater than your arm span by **more than 2 cm, you are considered a Tall rectangle). Use a bar graph to display the information. Use distinct colors for males and females.**

4. Use each of the regression equation calculated in this laboratory (See Section E) to predict your height based on the following variables: **length of your forearm, length of your upper arm, length of your upper leg** and **length of your lower leg**. How do the predicted values compare to the actual measurements?

5. Write a conclusion paragraph summarizing your most important findings in this laboratory.

6. **Connections:** What careers or professions do you think will benefit from the results of this type of research?

TABLE NO. 3
BODY MEASUREMENTS FOR **MALES (in centimeters)**

Student Number	Age	Weight (Kg)	Height (cm)	Arm Span	Right Fore-arm	Right Upper Arm	Right Upper Leg	Right Lower leg	Right Foot Length	Left Foot Length

TABLE NO. 4
BODY MEASUREMENTS FOR **FEMALES (in centimeters)**

Student Number	Age	Weight (Kg)	Height (cm)	Arm Span	Right Fore-arm	Right Upper Arm	Right Upper Leg	Right Lower leg	Right Foot Length	Left Foot Length

TABLE No. 5: **HEIGHT AND ARMSPAN (MALES AND FEMALES)**
(Centimeters)

MALES **FEMALES**

Student Number	Height (cm)	Armspan (cm)	Square	Tall Rect-angle	Wide Rect-angle	Student Number	Height (cm)	Armspan (cm)	Square	Tall Rect-angle	Wide Rect-angle

Note: If the difference between height and armspan is 2 cm or less you are considered a **Square.** If your height is greater than your armspan by more than 2 cm, you are a **Tall Rectangle**. If your armspan is greater than your height by more than 2 cm, your are a **Wide Rectangle.**

Figure 1: HEIGHT DISTRIBUTION FOR MALES (M) AND FEMALES (F)
(Frequency =Y and Height = X)

18																								
17																								
16																								
15																								
14																								
13																								
12																								
11																								
10																								
9																								
8																								
7																								
6																								
5																								
4																								
3																								
2																								
1																								
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
	< 146		146-150		151-155		156-160		161-165		166-170		171-175		176-180		181-185		186-190		191-195		>195	

STUDENT HEIGHT IN CENTIMETERS
(M= MALES AND F = FEMALES)

1. Construct a bar graph in the above grid for student height.
   Use two distinct colors for males and females.
2. In which height ranges are there more males than females?
3. In which height ranges are there more females than males?
4. Calculate the mean, mode, and median for males and females. Show work.
   (In statistics, the **Mean, Median and Mode** are called **Measures of Central Tendency**)
   (**Mean** is the average of the numbers; add all the numbers in a group and divide by the number of data).
   (**Mode** is the number or numbers that occurs most often).
   (**Median:** First, place all numbers in order from largest to smallest. For an **odd** number of data, the **Median** is the middle number.
   For an **even** number of data, the **Median** is the average of the two middle numbers).

APPENDIX C

ANTHROPOMETRY PRETEST/POSTTEST

PRETEST/POST-TEST
ANTHROPOMETRY LABORATORY

Teacher: M. Lightburn **Subject: Biology**

Name______________________________________ No._____ Period_____ Date ______

Directions: Choose the best answer for each statement. Place answers on blank space.

_____1. **Anthropometry** is the study of:
a. Artifacts built by humans. b. Fossils. c. human body measurement.

_____2. What major event in U.S. history (1860) produced a sudden demand for great quantities of uniforms:
a. Boy scouts b. parochial schools c. public schools d. Civil war

_____3. The human skeleton is divided into two major portions:
a) Axial and Cranial skeleton b) Appendicular and abdominal skeleton
c) Axial and Appendicular skeleton d) Cranial and abdominal skeleton

_____4. The human body is made up of ________ bones.
a. 206 b. 105 c. 200 d. 185

_____5. Red blood cells, white blood cells and platelets are produced in:
a. Blood b. Heart c. Bone marrow d. Heart and blood

_____6. One way to demonstrate that a student is scientifically literate, is if a student is able to:
a. Analyze and interpret data. b. Draw animals and plants c. Use a computer.

_____7. The middle value of a set of rank ordered data is:
a. mode b. median c. mean d. range

_____8. The average of a set of data is:
a. mode b. median c. mean d. range

_____ 9. The number(s) that occurs most often is:
a. mode b. median c. mean d. range

_____10. The circumference of the neck is approximately equal to:
a. ½ size of waist b. ¼ size of waist
c. 1/3 size of waist d. 1/8 size of waist

______11. The length of the foot is equivalent to the length of:
a. upper arm b. forearm c. upper leg d. lower leg

______12. Your arm span is always equal to your height.
a. true b. false c. don't know

______13. From the following data: 7,4,8,3,4,3 the **Mean** would be:
a. 4.83 b. 5.83 c. 6.83 d. 3.33

______14. From the following data: 7,4,8,3,4,3 the **Mode** would be:
a. 4 b. 3 c. 3.4 d. 3 and 4

______15. From the following data: 7,4,8,3,4,3 the **Median** would be:
a. 4 b. 3 c. 3.5 d. 4.5

APPENDIX D

ANTHROPOMETRY BACKGROUND INFORMATION

ANTHROPOMETRY

A. Anthropometry

Anthropometry (from the Greek *anthropos*, "human" and *metron*, "measure") is the biological science of measuring the size, weight and proportion of the human body. Prior to 1860, the belief was that each person's body was unique. The outbreak of the Civil War produced a sudden demand for uniform in great quantities. Using inches as standard measurement, the U.S. army discovered that certain body measurements tended to recur in combination with predictable regularity. This simple discovery made it possible to manufacture well-fitting clothes for a large population. Such discoveries and practices gave rise to **Anthropometry** or the measurement of individual with a view of discovering those patterns of physical and mental characteristics which recur among people differing in such dimensions as age, gender, and economic status.

B. Human Body

The human body as a whole can be subdivided into two major portions or components: **Axial** and **Appendicular.** The axial portion of the body consists of the head, neck, and torso or trunk; the appendicular portion consists of the upper and lower extremities. The human body, like that of all vertebrates, has bilateral symmetry. The left and right sides of the body are almost mirror images of each other.

The human skeleton is made up of 206 bones. The skeleton is also divided into two parts: Axial and Appendicular. The skull, vertebral column, and rib cage make up the **Axial Skeleton**. The bones of the axial skeleton protect vital organs such as the brain, heart, and lungs. The vertebral column, made up of a stack of vertebrae, holds the body upright and allows it to bend and twist into many positions. The arm and leg bones, with the bones of the pelvis and shoulder areas, form the **Appendicular Skeleton**. Bones and their associated tissues—cartilage, tendons, and ligaments—make up the skeletal system. Within bones are cavities that contain a soft issue called bone marrow. There are two types of bone marrow: yellow and red. Most bone contains yellow marrow, which is made up of blood vessels, nerve cells, and fat cells. Red marrow produces red blood cells, white blood cells (lymphocytes) and platelets (blood clotting elements).

C. Data Analysis

For students to be scientifically literate, they must be able to analyze and interpret data. After you have gathered raw data of body measurement, the next step is to mathematically analyze the data, graph the data, and to summarize trend. One way to analyze the data is to use basic descriptive statistics. Statisticians describe a set of data in two general ways. First, they compute a **measure of central tendency** or the one number that is the most typical of the entire set of data. Second, they describe the **variation**, or spread within the data.

The three different measures of central tendency are—the mean, median, and mode. Definitions and procedures for calculating the mean, median and mode are given below.

1. **Mode**: The value of the variable that occurs most often. If two or more values tie in having the most cases, report them as modes.

   Examples: a) 7,6,5,5,4,3 Mode = 5
   b) 15,13,12,11,9,9 Mode = 9
   c) 10,10,8,7,7,5,4 Modes = 10 and 7

2. **Median:** The middle value, after all of the cases have been rank ordered from highest to lowest. Half of the cases fall above the median value, half below.

   Examples: a) 5,3,4,6,5,7,1 rank highest to lowest: 7,6,5,**5**,4,3,1 Median = 5
   b) 9,11,13,9,15,12 rank highest to lowest: 15,13,**12**,**11**,9,9
   Median = $\frac{12+11}{2}$ = **11.5**
   c) 7,8,10,5,7,10,4 rank highest to lowest: 10,10,8,**7**,7,5,4 Median = 7

3. **Mean**: The arithmetic average or the sum of the individual values divided by the number of cases.

   Examples: $\text{Mean} = \frac{7+6+5+5+4+3}{6} = \frac{30}{6} = 5$

   $\text{Mean} = \frac{10+10+8+7+7+5+4}{7} = \frac{51}{7} = 7.3$

Measure of Variation: Refers to the spread within the data. Simple measures of variation are the **range** and **frequency distribution**.

4. **Range**: Is computed by finding the difference between the smallest (minimum) and the largest (maximum) measures of the individual values.

   Example: The height (in cm) of 10 students in Mr. Lightburn's first period class:
   180, 175, 165, 150, 170, 168, 172, 158, 177, 155
   Range = Largest value – smallest value = 180 – 150 = 30 cm.

5. **Frequency distribution**: Is grouping individual values by category.

   Example: Biology students in period 2 by grade level:
   9th Graders = 5
   10th Graders = 25
   11th Graders = 5

   Example: The total number of bell peppers harvested by color is:
   Red: 100
   Yellow: 150
   Green: 300

APPENDIX E

INSTRUCTIONS TO INPUT DATA IN GRAPHING CALCULATOR (TI-82)

INSTRUCTIONS FOR ENTERING DATA IN GRAPHING CALCULATOR (TEXAS INTRUMENT TI-82)

A. Entering Data

1. Turn on your calculator. Press **[ON]**
2. Press **[STAT]**
3. Press **[1] (edit)** or press **[ENTER]**
4. To clear previous data:
   a. Press up arrow (↑) to highlight L_1, then press **[Clear]** and **[Enter]**
   b. Press right arrow (→) once the (↑) once to highlight L_2, then press **[Clear]** and **[Enter]**
   c. To clear all Lists repeat step **b** as needed
5. To enter data in L_1
   a. Use arrow keys to move to the first position in L_1. **Note that at the bottom of the table, L_1 (1) will be visible.**
6. To enter data in other lists
   a. Press (→) to move to the desired list
   b. Repeat data entry procedure from previous step
7. Recheck your data carefully

B. Plot Data

1. Press **[2nd] [STAT PLOT] Review the 1st Stat Plot, if the set up is not what you need then:**

2. Press [1] or [ENTER]
   a. (↓) once to Type (first picture) Press **[ENTER]**
   b. (↓) once to **L1** then **[ENTER]**
   c. (↓) once then (→) to L2 then **[ENTER]**
   d. (↓) to first mark (box) then **[ENTER]**
3. Press **ZOOM** then press **9.** The plot of your data will be visible.

C. To obtain the linear equation

1. Press **STAT** then (→) to **CALC** (↓) to 5 on the menu then press **[ENTER]**, press **[L1] [,] [L2]** then **[ENTER]**
2. **The linear equation y = ax + b and then the values of a, b, and r appear**
3. Press **Y=**
4. Press **Clear** to clear all equations
5. Make certain the cursor is in Y_1
6. Press **VARS** then press **[5 (statistics)]**
7. On the menu that appears press (→) twice to EQ then press **[7 (Reg EQ)]**
8. The equation appears in Y_1
9. Now press **GRAPH**
10. You will see the graph of the line that "best fits" your data
11. In order to trace on the line, press **TRACE**. Notice that P_1 appears in the upper right corner of the screen allowing you to trace on the **stat plot**
12. Press (↑) and the cursor appears on the line and the coordinates are displayed at the bottom of the screen

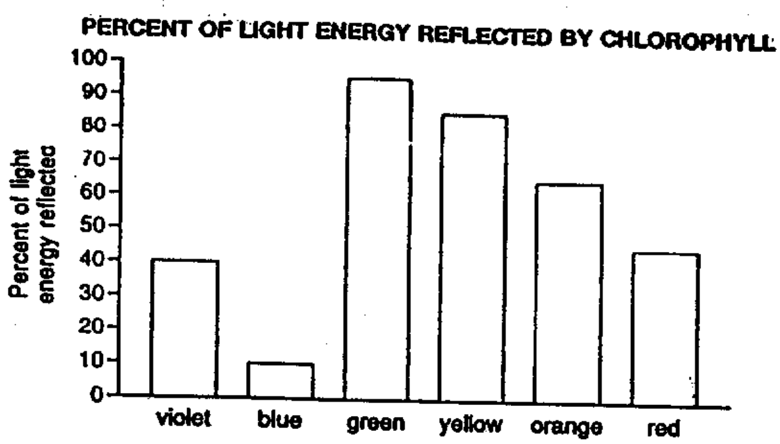
APPENDIX F

BIOLOGY PRETEST/POSTTEST

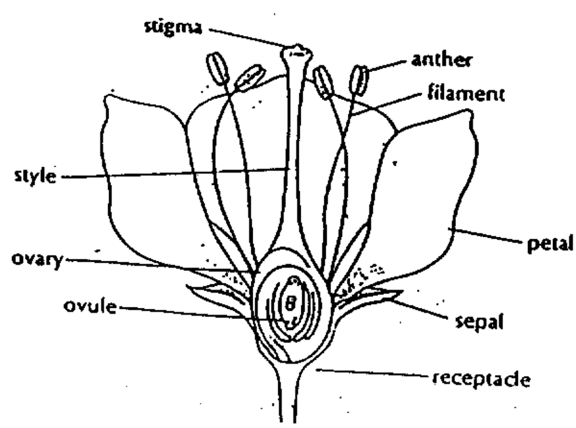
Biology Pre/Post Test
2000-2001

Directions: Please do not mark on this test. Mark the appropriate answer on the scantron.

1. According to the bar graph, which color of the spectrum is the most visible?
   a. Yellow
   b. Orange
   c. Blue
   d. Green



2. Study the diagram of the flower. The part of the flower where pollen is deposited is called the:
   a. Anther
   b. Style
   c. Stamen
   d. Sigma



3. Algae are organisms that live in water or very damp habitats. They do not have to deal with many of the stresses experienced by land (terrestrial) plants. The major difference in structure between algae and terrestrial plants is that:
   a. Algae have roots that anchor them to the bottom of the ocean.
   b. Terrestrial plants have roots that anchor them to the bottom of the ocean.
   c. Algae have vascular tissue and terrestrial plants do not.
   d. Algae have accessory pigments and terrestrial plants do not.

4. Earthworms are important for the environment because they:
   a. Eat and digest parasites.
   b. Aerate and condition the soil.
   c. Have compounds in there saliva that is used in medicine.
   d. Use the clitellum during reproduction.

5. The larval stage of a butterfly during metamorphosis is the:
   a. Caterpillar b.Egg c. Pupa d. Adult

6. Fish obtain oxygen by taking water in through this organ:
   a. Gills b. Mouth c. Skin d. All of the above

7. Many animals in this class mature in aquatic habitats and live out their adult lives on land. These animals are called:
   a. Reptiles b. Mammals c. Arthropods d. Amphibians

8. Organisms that must rely on external sources of heat to control their body temperatures are referred to as:
   a. Ectotherms b. Endotherms c. Oviparous d. Ovoviviparous

9. Organisms that have hair or fur, produce milk for their young, and can maintain their own internal temperature without an external heat source are called:
   a. Birds b. Mammals c. Reptiles d. Fish

10. Which of the following gases was not present in the primitive atmosphere at the time life is believed to have originated?
    a. Hydrogen b. Oxygen c. Ammonia d. Methane

11. Which of the following scientists discovered the structure of the DNA molecule?
    a. Johnson and Johnson c. Darwin and Lamarck
    b. Watson and Crick d. Pasteur and Montagne

12. One of the major differences between a plant cell and an animal cell is the presence of:
    a. Large vacuoles b. Cell wall c. Cytoplasm d. Both a and b

13. When two alleles are expressed simultaneously in heterozygous, the genetic principle demonstrated is called:
    a. Dominance b. Crossing over c.Translocation d. Codominance

14. Peppered moth changing colors in a polluted environment is an example of:
    a. Punctuated equilibrium   b. Speciation
    c. Natural selection   d. Adaptive radiation

15. The four bases of DNA are:
    a. Guanine, chlorine, adenine, thymine   c. Guanine, chlorine, adenine, phosphate
    b. Nucleotide, cytosine, phosphate, thymine   d. Guanine, cytosine, adenine, thymine

16. Within the structure of DNA, the two base pairs are called:
    a. Pyrimidines and purines   c. Nucleotides and phosphates
    b. Ribosomes and chromosomes   d. Bacteriophage and purines

17. Which is not a characteristic of evolution?
    a. Survival of the fittest by natural selection
    b. There is variation among members of a population
    c. Populations tend to produce more offspring than can possibly survive
    d. There is competition among the members of a struggling population

18. When two heterozygous (Rr) alleles for a specific trait are crossed, what percentage of the offspring will also be heterozygous?
    a. 100%   b. 25%   c. 50%   d. 75%

19. Sickle-cell anemia, Huntington's disease and Tay-Sach's disease are all examples of:
    a. Equilibrium   b.Genetic diseases   c. Sex-linked traits   d. Mutations

20. Evidence of evolution comes in the form of:
    a. Fossils   b. Similarities in DNA
    c. Homologous structures   d. Similarities in the embryos   e. All of these

21. Farmers breeding desirable crops and the breeding of dogs and horses are all example of:
    a. Natural selection   b. Mutations   c. Artificial selection   d. Transformation

22. Incomplete dominance in a flower with red parent (RR) and a white parent (rr) will result in which color flower?
    a. Red   b. White   c. Purple   d. Pink

23. A proposed solution or explanation of a scientific event in nature is called a:
    a. Conclusion   b. Hypothesis   c. Control   d. Theory

24. The factor that is tested in an experiment is the:
    a. Data   b. Hypothesis   c. Variable   d. Theory

25. Which group of elements combines to form practically all of the chemical compounds in living things?
    a. Carbon, hydrogen, oxygen, nitrogen   b. Carbon, sodium, chlorine, oxygen
    c. Carbon, hydrogen, phosphorus, nitrogen   d. Sulfur, phosphorus, carbon, oxygen

26. The main goal of science is to:
    a. Arrange a series of observations
    b. Arrange a series of tests
    c. Obtain proof of ideas
    d. Understand the world around us

27. The single most important rule in the laboratory is to:
    a. Follow your teacher's instructions exactly
    c. Do not work with live animals
    b. Always wear safety goggles in the lab
    d. Do not use electricity as source of heat

28. Paleontologists specialize in the study of:
    a. Animal behavior b. Animals c. Fossils d. Plants

29. The lens at the top of the microscope tube is called the:
    a. Diaphragm b. Ocular lens c. Objective lens d. Course adjustment

30. Matter is anything that has:
    a. Weigh and mass
    b. Weight and volume
    c. Mass and takes up space
    d. Weight and size

31. Which of these statements is not a component of the Cell Theory?
    a. Animal and plant cells are different
    b. All living things are composed of cells
    c. Cells are the basic units of structure and function in living things
    d. All cells come from pre-existing cells

32. The correct genus and species for man is:
    a. *Homo erectus* b. *Homo habilis* c. *Homo sapiens* d. *Australopithecus*

33. The largest bone in the body is found in the thigh. This bone is called the:
    a. Fibula b. Sternum c. Femur d. Cranium

34. The function of the reproductive system is:
    a. To provide a means for developing efficient systems
    b. Continuation of the species
    c. To provide a method for maintaining good health
    d. To allow species to protect their offspring

35. According to the food pyramid, a healthy diet consists of foods from which of the following food groups?
    a. Breads and cereals, fruits, vegetables, dairy and meats/proteins
    b. Breads, milk and fats
    c. Meat, fats, sugars
    d. Meat, poultry and fish

36. The sum of all the chemical processes that take place within an organism are called:
    a. Metabolism b. Homozygous c. Heterozygous d. Catabolism

37. The function of this system is to deliver oxygen, nutrients and other needed substances to the cells of the body:
a. Digestive   b. Circulatory   c. Skeletal   d. Integumentary

38. Which of the following is not a means of transmitting the AIDS virus from one person to another?
   a. From mother to child
   b. Contact with contaminated blood
   c. By donating blood
   d. Unprotected sex

39. Monerans have a nuclear region that is not surrounded by a nucleus. This would categorize them as:
   a. Eukaryotes
   b. Multicellular
   c. Prokaryotes
   d. Multinucleated

40. The mushroom portion of a fungus is actually called a(n):
   a. Fruiting body
   b. Stolon
   c. Rhizoid
   d. Imperfect fungi

APPENDIX G

STUDENT INTERVIEW QUESTIONS

STUDENT INTERVIEW FORM

Name:______________________________No._____Per____Date______

(Please be fair, honest, and sincere when answering these questions. Your input is important to me).

1. Give us your opinion about the Laboratory Human Anthropometric (Human Body Measurements).
   The objective of this assignment was to incorporate principles and concepts in mathematics, technology and science.

   a. Was it difficult to gather the measurements of the human body? Did you feel uncomfortable with any of the measurement?

   b. Was it difficult to compute the Mean, Mode and Median?

   c. Prior to this lab, did you ever use the Texas Instrument (TI-82) calculator?

   d. Did your teacher provide clear instruction for the use of the TI-82 calculator?

   e. Did you think the computations of the regression equations were an important part of the laboratory? Explain.

   f. Please describe the **pros (positive)** and **cons (negative)** of this lab assignment.

2. During each laboratory activity, you had the opportunity to work in cooperative learning group. What are the pros and cons of cooperative learning groups?

3. What activity or activities carried out during the year did you **enjoy most**?

4. What activity or activities carried out during the year did you **enjoy the least**?

5. What science classes would you like to take during the next three years of high school? (Chemistry, Physics, AP Biology, AP Chemistry, AP Environmental, Anatomy and Physiology, Marine Biology). **Please circle as many as you would like to take.**

6. What career would you like to pursue? What major factor would influence you in pursuing such career?

6. Which college or vocational school would you like to attend? Explain your answer.

7. What job activities are your parents involved in?

8. Would you like to be a scientist? Explain your answer.

9. Please draw your image of a scientist.

APPENDIX H

RESEARCH SUBJECT CONSENT FORM

RESEARCH SUBJECT CONSENT FORM

Prospective Research Subject: Read this consent form carefully. Please feel free to contact me if additional clarification is required. Your cooperation is deeply appreciated.

1. **Proposed Ph.D. Dissertation Title:** Design, Implementation and Evaluation of Anthropometry Activities for High School Science.

2. **Principal Investigator**: Millard E. Lightburn

   University Affiliation: National Key Centre for School Science and Mathematics, Curtin University of Technology
   GPO BOX U1987, Perth, WA 6845, Australia.

   Professional Affiliation: Biology Teacher at Miami Palmetto Senior High School, Miami- Dade County Public Schools.
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3. **Purpose of Research:**

   The main goals of the research are:
   a. To validate generally-applicable measures of classroom learning environments and student attitudes to science.
   b. To evaluate the student-centered anthropometric activities in terms of:
      b.1 Student performance as demonstrated by their ability to make accurate measurements, to organize data in tables, charts, and graphs and to compute and interpret basic descriptive statistics.
      b.2 Student attitudes to science.
      b.3 Student perceptions of their classroom learning environment.
   c. To investigate associations between the classroom learning environment and the student outcomes of performance and attitudes.

4. **Procedures:**

Students will actively participate in two sets of activities:

A. **Anthropometric Studies**: Students will make measurements of different bones of their bodies, share some measurements with class members and statistically analyze class data using graphing calculator. The main goal of this portion of the research, is to teach students how to make accurate metric measurements and how to process the data by using principles learned in mathematics and statistics.

B. **Science Attitude and Perception of Laboratory Environment:**

Students will respond to a survey in which we will ask for their thoughts about science and their perceptions about the science laboratory.

There are no right or wrong answers for the questions on the survey. The only correct responses are those that are true to you.

A small random sample of students will be interviewed in order to better understand their thoughts and perceptions of the science laboratory.

The focus group of this research will be Biology students enrolled at Miami Palmetto Senior High School in Miami, Florida.

5. **Projected Timetable of Research**

August-September 2001	Request parental permission to initiate survey and data collection.
September-November 2001	Administer survey and collect data.
December 2001-February 2002	Analyze and interpret data.
March-October 2002	Write various drafts of thesis chapters.
November 2002	Submit thesis.

6. **Confidentiality**

All social research involves ethical issues. This is because the research involves collecting data from people and about people.

Students will be informed of the aim of the research project. They also will be informed that privacy and confidentiality of the data generated in the research will be strictly adhered to. Using number or initials instead of names in the final report will provide anonymity. Students will be informed of the voluntary nature of their participation in this research. They will have a choice to whether or not they get involved in the study, and they will be free to withdraw at any time.

AUTHORIZATION

I have been informed of the scope and nature of Millard E. Lightburn's proposed Ph.D. dissertation "**Design, Implementation and Evaluation of Anthropometry Activities for High School Science**". I understand the voluntary nature of my child's participation in this study and that my consent to participate does not take away any legal rights in the case of negligence or other legal fault of anyone who is involved in this study. I further understand that nothing in this consent form is intended to preempt any applicable federal, state or local laws regarding informed consent.
I understand that my child will be free to withdraw at any time during the duration of this research.

Student name ____.
First, middle initial and last name

Student age: __________ Gender _____ Grade level _________

Parental Consent

I, ________________________________ (Print name of parent or legal guardian) **give my parental consent for my child,** _______________________(Print Child's name) **to participate in this research study**.

____

Parent's or Legal Guardian Signature Date
(Parental Consent)

****

Refusal to Participate

I, ________________________________(Print name of parent or legal guardian) **do not give my parental consent for my child,** _________________________(Print Child's name) **to participate in this research study**.

____

Parent's or Legal Guardian Signature Date
(Parental refusal to participate)

APPENDIX I

SCHOOL DISTRICT AUTHORIZATION TO CONDUCT RESEARCH (MIAMI DADE COUNTY PUBLIC SCHOOLS RESEARCH REVIEW COMMITTEE)