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ABSTRACT

The study involved implementing and evaluating activities that actively engage 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. 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. Students integrated concepts in science, mathematics, and statistics, using technological tools (graphing calculators, computers) to process information. The purpose of this research was to evaluate these student-centered activities in terms of performance assessment, student attitudes, and perceptions of science classroom environment. The study has the potential to help other science teachers to apply these ideas in their classrooms, and it contributes an interesting application of classroom environment assessments in the evaluation of educational innovations. (Contains 49 references.) (Author/MM)

CLASSROOM ENVIRONMENT AND STUDENT OUTCOMES ASSOCIATED WITH USING ANTHROPOMETRY ACTIVITIES IN HIGH SCHOOL SCIENCE

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Classroom Environment and Student Outcomes Associated with Using Anthropometry Activities in High School Science

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1. Rationale and Introduction

The study involved implementing and evaluating activities that actively engage 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. 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. Students integrated concepts in science, mathematics and statistics, using technological tools (graphing calculators, computers) to process the information. The purpose of this research was to evaluate these student-centered activities in terms of performance assessment, student attitudes and perceptions of science classroom environment. The study has the potential to help other science teachers to apply these ideas in their classrooms, and it contributes an interesting application of classroom environment assessments in the evaluation of educational innovations.

2. Objectives

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

3. Background

Anthropometry

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 lends itself as 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 also 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). In the present study, students were trained 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.

Mosenthal and Kirsch (1994) stated that, before 1860, the belief was that each person's body was unique. They described that the outbreak of the Civil War produced a sudden demand for uniforms in great quantities. Using inches as a standard metric, 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.

Other researchers have successfully used anthropometric activities in the elementary, middle school and high school settings (Greeley & Reardon, 1997; Knill 1991, 1995; Neufeld, 1989; Pagni, 1979; Shaw, 1984).

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 (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). They give a step-by-step procedure stating how to input the data in the graphing calculator. 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 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.

These anthropometric activities described in this literature review as well as those activities described in the present study, are the type of practical applications that are likely to get students interested in science and mathematics.

In the present study, students made anthropometric measurements during activities requiring the application of prior and new knowledge to gather, process and analyze data. A sample of information gathered by the students is given in Appendix A. This information was used to compile central tendency statistics (mean, mode, median), standard deviation and regression equation (see Appendix A).

Learning Environments and Attitudes to Science

Although the instructional activities provided good-quality performance measures of student achievement, the affective domain (attitudes and classroom environment perceptions) should not be left out when evaluating educational innovations.

A strong history of research on classroom learning environments (Fraser, 1991, 1998) has established several trends relevant to our study. First, several widely applicable and carefully validated questionnaires for assessing student perceptions of classroom environments formed the starting point for the development of a learning environment questionnaire for use in the present study. 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. Third, the proposed study also followed past research, which has explored associations between the nature of the classroom learning environment and students' achievement and attitudes (McRobbie & Fraser, 1993).

For the purposes of our study, we adapted attitude scales from the Test of Science-Related Attitudes (TOSRA) (Fraser, 1981) and from the scales developed by Doepken, Lawsky & Padwa (1993).

Fraser (1998) conducted an extensive 30 year meta-analysis (1960s to 1990s) of the literature related to the determinants and effects of the social and psychological aspects of the learning environments of classrooms and schools. He made a comparative analysis of 9 classroom environment instruments, one of which is the Science Laboratory Inventory (SLEI). A modified version of SLEI was used in the present study, to determine student perception of the classroom learning environment.

Lewin (1936) and Murray (1938) were probable the first to point out that human behavior is a function of the interaction between the individual and its environment. This concept may have served as foundation for the development of the first learning environment scales.

Walberg's Learning Environment Inventory (LEI) (Walberg and Anderson, 1968) and Moos' Classroom Environment Scale (CES) (Moos 1974, 1979; Moos & Trickett, 1987) were some of the earliest learning environment scales. Since the pioneering works of Walberg and Moos, research on classroom learning environment has grown extensively (Fraser, 1998). However, it wasn't until the early 1990s that researchers felt that there was a need to develop special learning environment scale to assess the unique psychosocial aspects of the science laboratory. Fraser, McRobbie and Giddings (1993), developed one of the first survey instruments to assess the learning environment of science laboratory classes at the high school level (Science Laboratory Inventory (SLEI)). SLEI was later refined in 1995 (Fraser, Giddings & McRobbie, 1995; Fraser & McRobbie, 1995). The SLEI was field tested and validated simultaneously with a sample of over 5400 students in 269 classes in six different countries (USA, Canada, England, Israel, Australia and Nigeria) and cross-validated with 1594 Australian students in 92 classes (Fraser & McRobbie, 1995), 489 senior high school biology students in Australia (Fisher, Henderson & Fraser, 1997) and 1592 high school chemistry students in Singapore (Wong & Fraser, 1995).

4. Research Methods

Sample Selection

One hundred fifty-eight students participated in the anthropometric study. Twenty-four of these students (11 girls and 13 boys) were selected for the qualitative component of the research involving interviews. The target students selected to participate in the interview are all honors student in the researcher's biology classes. These students were selected because they are more involved in classroom interactions and they are high achievers. Other sources of information used to assess student achievement were based on a Biology pretest and posttest administered to 558 students, and the final report card in Biology for the school year 2000-2001 collected from 662 students.

For the quantitative portion of the study involving the validation of questionnaires and investigating associations between environment and student attitudes, a larger sample covering 761 students in 25 classes was used.

The use of different sized samples (grain sizes) for different research questions in learning environment research (Fraser 1999) has been used in mixed-method research (Lee, 2001; Aldridge & Fraser, 2000; Tobin & Fraser, 1998), and was used in the collection of quantitative and qualitative data in this study.

The study 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 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.

Data Sources

We used both quantitative and qualitative methods to generate answers for the same research problem as recommended by Tobin and Fraser (1998). Within the quantitative approach (questionnaire surveys), the study was conceptualized in terms of variables and relationships between them, while the qualitative approach (interviews) provided a way of finding out the subjects' views (Erickson, 1998).

Several authors and researchers in the field of science education are increasingly recommending combining quantitative and qualitative methods in the same study (Anderson & Arsenault, 1998; Erickson, 1998; Houtz 1995; 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.

Our 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 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 by use of descriptive statistics and develop predictive linear regression equations.

The survey instrument that measured student attitudes towards science was based on selected items from the Modified Fennema-Sherman Science Attitude Scales (Doepken, Lawsky, & Padwa, 1993) and Test of Science-Related Attitudes (TOSRA) (Fraser, 1981). This instrument consisted of four scales (Personal Confidence about Science, Usefulness of the Subject Matter, Perception of Teacher's Attitudes, and Attitude to Scientific Inquiry). Each scale consists of six items for a total of 24 questions. Each item is based on a five-point

Likert scale with the alternatives of strongly *agree, agree, not sure or can't answer, disagree* and *strongly disagree*.

Student perceptions of classroom learning environment were measured with a modified instrument based on the Science Laboratory Environment Inventory (SLEI) (Fraser, Giddings, & McRobbie, 1995; Fraser, McRobbie, & Giddings, 1993). This survey instrument also consisted of four scales (Student Cohesiveness, Integration, Rule Clarity and Material Environment), with six items for each scale for a total of 24 questions. Each item was also based on a five-point response scale with the alternatives of *almost never, seldom, sometimes, often* and *very often*.

Pretests and posttests were administered before and after the instructional activities took place to determine if improvement in knowledge and understanding had occurred. During the implementation of the anthropometric activity, students' performance was assessed in order to determine if they mastered the concepts.

Data Analysis and Interpretation

Data from the modified measures of classroom environment and attitudes were subjected to factor and item analyses. Refined scales were validated in terms of factor structure, internal consistency reliability and ability to differentiate between classrooms. For SLEI, we were unable to obtain factor structure analysis for our sample.

Students' achievement assessment for the anthropometric activity was based on how well they processed data using graphing calculators, graphing software and electronic spreadsheets. Students also applied concepts learned in their mathematics classes such as graphing skills, identifying dependent and independent variables, median, mode, mean and standard deviation.

Another way of evaluating student academic performance on the anthropometric activities was to measure changes in achievement on a pretest and posttest. The pretest was done at the beginning of May 2001 and the posttest at the end of May 2001.

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

Associations between students' perceptions of their classroom environment and student attitudes were investigated by use of simple correlation and multiple regression analysis using two units of analyses. The simple correlation (r) describes the bivariate association between an attitudinal outcome and a SLEI scale. The standardized regression weight (β) characterizes the association between an attitudinal outcome and a particular learning environment scale when all other SLEI scales are mutually controlled.

In order to identify the individual classroom environment scale, which contributes most to the variance in student attitudes, standardized regression coefficients (β) were computed.

The qualitative data were collected primarily through written interviews and when warranted, oral interviews were conducted. The purposes of the interviews were twofold. First, the researchers wanted to expand and gain clarification on some of the responses given on the attitude and environment surveys (quantitative portion of the study). Second, we wanted to assess how students viewed the anthropometric activities.

5. Findings

5.1 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) 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. Some original items were removed because their factor loading were lower than 0.40.

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

In the present research, a modified version of SLEI was used. The version used in this study consisted of four scales (Integration, Rule Clarity, Student Cohesiveness, and Material Environment), containing six items in each scale. 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.

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 4 scales and 24 items of SLEI using both the individual student and the class means 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 5.1). In both cases, these coefficients easily exceed the threshold of 0.60, which is often considered as acceptable for research purposes (Nunnally, 1967).

Table 5.1 Internal Consistency Reliability (Cronbach Alpha Coefficient) and Ability to Differentiate Between Classrooms (ANOVA Results) for Two Units of Analysis 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 5.1 shows the result of the analysis in terms of eta^2 statistics (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 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 other authors have reported strong support for factor analysis of SLEI ((Lee, 2001; Fraser, McRobbie & Giddings, 1993), we were unable to replicate this structure with the present sample.

5.1.2 Validity and Reliability of the Modified Fennema-Sherman Attitude Scale

When the attitude instrument was subjected to item and factor analyses, three items from the scale Perception of Teachers Attitudes were found to have 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.

A factor analysis (principal components with varimax rotation) was conducted for the attitude items for the total sample of 761 biology students. The results for the factor loading for the final factor analysis are shown in Table 5.2. For 23 of the 24 items in Table 5.2, 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.

Table 5.2 reveals that 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 analyses reported in Table 5.2 provide strong support for the factorial validity of the attitude questionnaire.

Table 5.2: Factor Loadings for the Science Attitude Scales (Fennema-Sherman Scale)

	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.

Item analysis was used for the 4 scales and 22 items of 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 coefficients 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 5.3). 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 SLEI.

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 (Table 5.3). 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 5.3 Internal Consistency Reliability (Cronbach Alpha Coefficient) and 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	0.62
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

5.2 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 attitude to science and student perceptions of their laboratory-learning environment. This was accomplished by conducting *t*-tests for paired samples for pretest and posttest for biology and anthropometry. To determine associations among attitudes to science, classroom environment and cognitive outcome, the data was subjected to *t*-tests and effect sizes for paired samples to determine if differences were statistically significant. Results are given in subsections 5.2.1, 5.2.2. and 5.2.3.

5.2.1 Changes in Achievement

Two sources of information were used to assess changes in academic achievement: Biology Posttest score (this was done for comparative purposes to measure increase in achievement over the pretest) and the score for the laboratory activity on Anthropometric at posttest stage (this activity was specially designed for this research).

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 (pre-test) 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

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 graphing calculators to determine statistical correlation between different variables and compute predictive regression equations. A sample of the type of information gathered by the students is given in Appendix A. This information was used to compile central tendency statistics (mean, mode, median), standard deviation and regression equation (see Appendix A). The 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. One hundred and fifty-eight (158) students participated in the anthropometric activity and tests.

Another method of evaluating student academic performance on the anthropometric activities and Biology test was to measure changes in achievement on a pretest and posttest. Table 5.4 reports average item mean, average item standard deviation and t tests for paired samples for differences between pretest and posttest scores in anthropometric and Biology achievement using the individual as unit of analysis.

Table 5.4 Average Item Mean, Average Item Standard Deviation, effect size and *t* Tests for Differences Between Pretest and Posttest Scores for Paired Samples in Biology and Anthropometric Achievement for the Individual as the Unit of Analysis.

Scale	Average Item Mean Score		Standard Deviation		Differences Between Pre and Post Scores	
	Pretest	Posttest	Pretest	Posttest	Effect Size	*t*
Biology	20.29	25.07	5.73	6.21	0.80	-20.28**
Anthropometric	1.20	2.46	1.14	1.20	1.08	-12.97**

$^{**}p<0.01$

Table 5.4 shows that the average item mean on the anthropometric pretest was 1.20 and the posttest was 2.46 (out of a total possible score of 4.0). The posttest score is approximately double the pretest score (Table 5.4). A *t*-test for paired samples for differences between the pretest and posttest scores in Anthropometric indicates statistically significant changes ($p<0.01$) (Table 5.4). In order to estimate the magnitudes of the pretest/posttest differences (in addition to their statistical significance), the effect size was calculated. The effect size of 1.08 for the individual as the unit of analysis suggests a substantial difference between the pretest and posttest scores.

Table 5.4 also shows that the average item mean for the Biology pretest was 20.29 (40 was the maximum possible points) and on the posttest mean score was 25.07. The posttest showed an increase of 25% over the pretest. A *t*-test for paired samples for differences between the pretest and posttest scores in Biology was statistically significant ($p<0.01$) (Table 5.4). In order to estimate the magnitudes of the pretest and posttest differences (in addition to their statistical significance), the effect size was calculated. The effect size for the change in Biology scores between pretest and posttest was over three quarters of a standard deviation

(0.80) for the individual as the unit of analysis, which suggests a substantial difference between the pretest and posttest scores.

5.2.2 Achievement Measures and Attitude

Gender related differences between achievement measures and attitude were analyzed. Three sources of information were used to determine gender differences in academic achievement. The sources of achievement were: Final Report Card grade in Biology (this refers to student final coursework grade in Biology), Biology Posttest score (this was done for comparative purposes to measure increase in achievement over the pretest), and the score for the laboratory activity 'Anthropometric' at the posttest stage (this was specially designed for this research).

At the end of the 2000-2001 school year we collected data on student final grade in Biology, which was used as another measure of achievement. It refers to student performance grades on the mandate curricular content taught by all science teachers during the school year. Data was collected from 662 students. The letter grade scale is A = 4 points (90-100 %), B = 3 points (80-89 %), C = 2 points (70-79 %), D = 1 point (60-69 %) and F = 0 points (0-59 %).

Gender-related differences were explored for the attitude scale, and achievement 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. Because the multivariate test yielded a statistically significant result using Wilks' lamba criterion, a *t* test for paired sample was conducted for each dependent variable. Average item means were used because of differences in the number of items in the different scales.

The sample size for the gender related differences portion of this study was 760 students (396 males and 364 females) distributed among 25 classes.

The results presented in Table 5.5 show the average item mean and average item standard deviation for male and female students' responses to attitude to science, and achievement scales. Also results for *t* tests and effect sizes are shown. The results in Table 5.5 shows that there is statistically significant ($p<0.05$) gender-related differences in student's 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 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 5.5).

German (1988) concluded that attitude correlated more substantially with formative scores from laboratory scores and semester grades than with the course and laboratory pretests. He found that attitude toward science in school accounts for about 16% of the variation in classwork. He concludes that students with more positive attitudes attend better to classroom instruction, lab exercises, studying, and homework than students with a less positive attitude.

Table 5.5 Average Item Mean, Average Item Standard Deviation and *t* Test for Paired Samples for Difference Between Males and Females on the Attitudes to Science 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*
Attitude 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*
Achievement						
Report Card Grade	2.53	2.63	0.63	0.71	0.15	-1.51
Biology Posttest	24.61	23.96	4.19	4.05	0.16	1.66
Anthropometric Posttest	2.36	2.43	0.72	0.60	0.11	-0.51

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

N= 396 Male students and 364 female students in 25 classes.

5.2.3 Achievement Measures and Learning Environment

Gender-related differences were also explored for the Learning Environment scale (SLEI), and achievement 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.

Table 5.6 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. No statistically significant gender differences were found for the scales Integration and Material Environment. 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 (Henderson, Fisher, & Fraser, 1998; Fraser, Giddings, & McRobbie, 1995). 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 the gender differences for these two classrooms environmental scales are of a reasonable magnitude.

No statistically significant differences were found between male and females students in their achievement scores on any of the three measures. These results are different from those obtained by Zerega, Haertel, Tsai and Walberg (1986). When they analyzed data from the 1976 National Assessment of Educational Progress (NAEP) using a sample size of 3049 17-year old high school students, males scored higher on science achievement and motivation, and perceived their classroom environments more positively than did females. They concluded that science was still viewed as a male domain, that it is very important to be accepted by peers in high school, and that, because girls are not supposed to be good in science according to the stereotype, they confirm what peers expect. The results of our study could possibly suggest that, in the 2000s at my school, female students do not consider Biology to be so much of a male domain anymore. Perhaps this could be reinforced by the fact that females also showed no statistically significant difference from their male counterparts in scores on two main attitudes to science scales, namely, Personal Confidence about Science and Usefulness of Subject Content.

Arambula (1995) investigated gender participation patterns in State-level science competitions over approximately 35 years of competition in Hawaii. The examination of topic preferences over the years indicates that both boys and girls have traditionally favored life science; however, boys have been and continue to be more likely to prefer physical, earth and mathematics/computer science projects than girls. This clearly suggests that different type of high school sciences could lead to differences in gender preferences and possibly differences in cognitive outcomes.

5.3 Associations Between Students' Outcome and their Classroom Environment Perceptions

Another goal of this research was to investigate the associations between students' outcome and their perception of the learning environment. The association between attitude and student perception of the learning environment will be discussed in section 5.3.1 and the association between achievement and learning environment will be discussed in section 5.3.2.

5.3.1 Association Between Perception of Classroom Environment and Attitude

Associations between students' perceptions of their classroom environment and student attitude were investigated by use of simple correlation and multiple regression analyses using two units of analysis (Table 5.7). The simple correlation (r) describes the bivariate association between an attitudinal outcome and a SLEI scale. The standardized regression weight (β) characterizes 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.

Table 5.7 shows generally 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. All statistically significant correlations are positive.

Table 5.7 Simple Correlation and Multiple Regression Analyses for Associations Between Student Attitudes and Dimensions of the SLEI

Scale	Unit of Analysis	Personal Confidence about Science		Usefulness of Subject Content		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 5.7 shows the multiple correlation (R) between each attitude scale and the SLEI of four Learning Environment scales. Multiple correlations for different attitudes scales range from 0.12 to 0.27 and all were 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 Inquiry.

In order to identify the individual classroom environment scale, which contributes most to the variance in student attitudes, standardized regression coefficients β were examined (Table 5.7).

When using the individual as the unit of analysis, the β values in Table 5.7 indicate that Integration is a significant independent predictor of all attitudinal scales except for 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 indicate an inverse relationship. Rule Clarity is not a significant independent predictor of any attitudinal scale.

When using the class as the unit of analysis, Integration is a significant independent predictor of all attitudinal scales, except for 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.

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).

5.3.2 Associations Between Achievement and Learning Environment (SLEI)

As shown in table 5.8, 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 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).

Biology report card scores were recorded for 662 students in 25 classes. A total of 598 students in 25 classes took the biology posttest and 158 students in 6 classes participated in the anthropometric activity. For anthropometric, the sample size (N=6) was too small to generate dependable statistics for class means.

When using the individual student as the unit of analysis 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 5.8). Talton and Simpson (1987) reported similar results. They found that 56% to 61% of the variance in attitude toward science could be accounted for by students' attitude toward the classroom environment; 8% to 18% of the variance in achievement was accounted for by both attitude toward classroom environment and attitude toward science; and 5% to 14% of the variance in student achievement was predicted by the students' attitude toward the classroom environment alone.

The simple correlation (r) values for the Biology posttest score showed a strong statistically significant ($p<0.05$) correlation with each of the four SLEI scales (Table 5.8); however, there is a stronger statistical correlation ($p<0.01$) at the individual level.

The simple correlation (r) values in Table 5.8 show that the final report card grade in Biology is statistically significantly correlated ($p<0.05$) with two classroom environment scales, Integration and Student Cohesiveness at the student level and none at the class level of analysis.

The only statistically significant simple correlation (r) ($p<0.05$) for the anthropometric activity 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. Only 158 students distributed among 6 classes took the anthropometric posttest. This number was probable too small to generate dependable statistics (Table 5.8).

Table 5.8 Simple Correlation and Multiple Regression Analyses for Associations Between Student Achievement and Dimensions of the SLEI.

Scale	Unit of 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, the sample size (N=6) was too small to generate dependable statistics for class means.

The bottom of Table 5.8 shows the multiple correlation (*R*) between SLEI 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 5.8). However, when using the class means as a unit of analysis, the set of dimensions of 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 number of students who participated in the activity (158 students) and responded to the posttest (Table 5.8).

In order to identify the individual classroom environment scales, which contribute to the variance in student achievement, standardized regression coefficient β were examined (Table 5.8). The standardized regression coefficient β in Table 5.8 indicate that Integration, Rule Clarity, Student Cohesiveness and Material Environment were significant independent predictors of the Final Biology Report Card grade for both units of analyses.

Integration is the only significantly independent predictor of the Biology posttest score (Table 5.8) when using the individual as the unit of analysis. No significant independent predictors were found for the anthropometric post test score.

These results suggest that integration of theoretical concepts with laboratory activities (Integration), using cooperative learning groups (Student Cohesiveness), and using appropriate laboratory materials and equipment, (Material Environment) are likely to lead to positive achievement outcomes at the end of the school year.

We 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) reported similar findings. They found that classroom environment possessed the strongest relationship with 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 achievement in science.

5.4 Student Perception on the Anthropometric Activity

One of the objectives of the second aim of this research was to obtain student perceptions of the anthropometric laboratory activity. Student feedback forms the basis for the qualitative part of the study. The qualitative data were collected mostly through written interviews and orally, only when clarification was warranted.

The purposes of the interviews were twofold. First, we wanted to expand and gain clarification on some of the responses given on the attitude questionnaire and environment survey (quantitative portion of the study). Second, we 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 target students are all honors student 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.

The findings of the qualitative portion of the study reveal that both boys and girls believe that the anthropometric activity was a good learning activity. However it was considered too time-consuming. They also agreed that the activity integrated science and mathematics skills and that they learned how to use the graphing calculator to develop regression equations. They also indicated that cooperative learning activities are important, but sometimes members of the group don't get along. 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.

Students were asked what were the positive perceptions and negative perceptions of cooperative learning groups. Some of the 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."

The interviews shed important light in term of improving the understanding of 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 laboratory activities were excellent ways of integrating concepts learned in science classes and also of promoting cooperative group work

6. Conclusion

A major educational goal is that all students should achieve scientific literacy. The central function of the *National Science Education Standards* (National Academy of Science, 1996) was to spell out a vision of science education that would make scientific literacy for all a reality in the 21st century. Two of the six major areas of science teaching standards are the planning of inquiry-based science programs and the development of environments that enable students to learn science. The learning goals of this anthropometric activity reflect the vision promoted in the *National Standards in Science Education*, and the activities are appropriate for the intended student population. Hopefully this study will provide insights that other science teachers can apply in their classrooms.

Factor and item analyses supported the factorial validity and internal consistency reliability of the classroom environment questionnaire and the attitude questionnaire. Past research (Fraser, 1994) was replicated in that statistically significant associations were found between student attitudes and classroom environment.

Sizeable effect sizes and statistical significance were found for the pretest-posttest scores on the achievement measures.

Students demonstrated ability to make accurate anthropometric measurements and were able to process the statistical data using graphing calculators and electronic spreadsheet.
Students considered the anthropometric activity a good learning activity but it should be probable broken down into various activities.

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

The results of this study 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. Positive attitude would more likely be displayed when students work in cooperative learning groups (Cohesiveness) and they perceived that their behavior in the laboratory is guided by formal rules (Rule Clarity).

A unique feature of this research is that it has 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).

APPENDIX A

Table 1 in this appendix gives a sample of how anthropometric data were compiled. From the data compiled in the laboratory, student computed central tendency statistics, standard deviation and linear regression equation.

Samples of some of the statistics computed are the following.

Example No. 1 Computation of central tendency and deviation statistics using student height.

Heights from Table 1 are rearranged in descending order:

189,178, 176, 176, 176, 172, 171 170, 170, 169, 166, 165, 164, 162, 157, 157, 153, 148, 142

Mean: 166.4 Median: 169 Mode: 176 Maximum: 189 Minimum: 142

n= 19 Standard Deviation: 11.4 Range = 47

Example No. 2 Computation of linear regression equation of height (y) versus length of right foot (x) by use of least-squares fit $(y = ax + b)$ a = slope b = y-intercept

Height (y): 170, 157, 178, 176, 164, 189, 172, 148, 176, 162, 165, 171, 157, 176, 142, 153, 170, 166, 169

Right Foot (x): 27, 25, 29, 27, 26, 28, 27, 21, 27, 23, 26, 26, 22, 27, 22, 23, 28, 26, 23

$Y = ax + b$ $a = 4.04498$ $b = 63.5408$ $r = 0.84$

$Y = 4.04498(X) + 63.5408$

This equation has good predictive value. For example if a shoe print measuring 27 centimeters is found in the classroom, one can use the regression equation to estimate the student height. (Y= 4.04498 (27) + 63.5408 = 172.76 cm (5'6") would be an estimate of the person's height).

Example No. 3 (Other interesting results that can be derived from Table No. 1)

For student No. 22 in Table #1, the following computation can be made.

1. Student height is **6.3** times the length of his right foot (divide height by foot length).
2. Student height is **6.8** times the length of his forearm (divide height by forearm length).
3. Student height is **5.0** times the length of his upper arm (divide height by upper arm).
4. Student height is **3.3** times the length of his upper leg (divide height by upper leg)
5. Student height is **3.7** times the length of lower leg (divide height by length of lower leg).

Table 1 Summary of Body Measurements for Boys
(in Centimeters)

Student Number	Age	Weight (Kg)	Height	Arm Span	Right Forearm	Right Upper Arm	Right Upper Leg	Right Lower Leg	Length Right Foot
22	16	93	170	173	25	34	52	46	27
05	13	41	157	157	22	26	43	38	25
06	15	85	178	181	27	31	48	51	29
24	17	65	176	179	29	32	44	43	27
31	17	74	164	160	28	31	45	40	26
32	18	67	189	195	32	31	44	52	28
14	13	64	172	183	29	37	48	54	27
21	14	46	148	149	23	25	38	37	21
34	16	86	176	183	24	30	43	47	27
09	13	44	162	160	28	28	41	42	23
07	13	44	165	172	24	30	41	44	26
29	17	67	171	178	24	35	42	41	26
19	13	49	157	158	22	21	39	39	22
15	13	66	176	171	26	28	40	48	24
17	13	40	142	145	25	27	37	41	22
18	13	52	153	157	22	29	36	41	23
30	17	110	170	183	26	30	47	43	28
02	13	70	166	175	23	30	40	42	26
08	14	51	169	165	22	29	49	39	23

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