



Understanding of statistical data analysis among elementary education majors
by Cynthia Skillingberg Thomas

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Education
Montana State University

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Abstract:

In the next 10 years, United States elementary, middle, and secondary schools will hire 2 million new teachers to meet rising enrollment demands and replace an aging teaching force. Half of United States teachers will retire during the same period. Given these projections and the fact that 21% of US teachers currently have less than a college minor in their principal teaching area, the education of preservice teachers must become a national priority. The purpose of this study was to determine to what degree elementary education majors acquire and retain the statistical data analysis content required for elementary and middle school as defined by the NCTM. A test instrument was developed and given to four groups of students ($n=232$) at Montana State University-Bozeman. Two-way ANOVAs and multiple regressions were done to determine if independent variables (age, gender, level of high school preparation, number of college math/stat classes taken and enrollment in the Math Option) influenced achievement in statistical data analysis. The overall conclusion was clear: Whatever gains are achieved in the content mathematics classes are lost by the end of student teaching. Consequently, students graduating from the elementary education program do not possess the content knowledge required to meet current professional standards. Neither age nor gender was determined to be statistically significant when trying to explain variability in total achievement or achievement in any of the five subtests. No significant difference in achievement between the students who were enrolled in the math option and those who were not was found, however discrepancies in the data presented by students led the researcher to doubt these results. Multiple regression analysis revealed that the set of independent variables did explain a significant proportion of the variability in achievement. However, even though the findings are statistically significant ($R^2=.123$) they are of little practical significance. Recommendations are given for changes in math content and methods courses for elementary education majors. Test instrument is included.

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AMONG ELEMENTARY EDUCATION MAJORS

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A dissertation submitted in partial fulfillment
of the requirements for the degree

of
Doctor of Education

MONTANA STATE UNIVERSITY - BOZEMAN
Bozeman, Montana

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Of a thesis submitted by

Cynthia Skillingberg Thomas

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Dr. William D. Hall

William D. Hall
(Signature)

4.3.00
Date

Approved for the Department of Education

Dr. Gloria Gregg

Gloria A. Gregg
(Signature)

4/3/00
Date

Approved for the College of Graduate Studies

Dr. Bruce McLeod

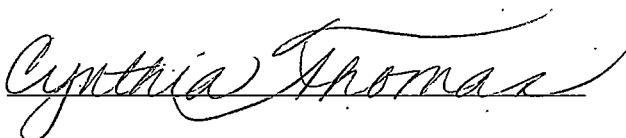
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Abstract

In the next 10 years, United States elementary, middle, and secondary schools will hire 2 million new teachers to meet rising enrollment demands and replace an aging teaching force. Half of United States teachers will retire during the same period. Given these projections and the fact that 21% of US teachers currently have less than a college minor in their principal teaching area, the education of preservice teachers must become a national priority. The purpose of this study was to determine to what degree elementary education majors acquire and retain the statistical data analysis content required for elementary and middle school as defined by the NCTM. A test instrument was developed and given to four groups of students ($n=232$) at Montana State University-Bozeman. Two-way ANOVAs and multiple regressions were done to determine if independent variables (age, gender, level of high school preparation, number of college math/stat classes taken and enrollment in the Math Option) influenced achievement in statistical data analysis. The overall conclusion was clear: Whatever gains are achieved in the content mathematics classes are lost by the end of student teaching. Consequently, students graduating from the elementary education program do not possess the content knowledge required to meet current professional standards. Neither age nor gender was determined to be statistically significant when trying to explain variability in total achievement or achievement in any of the five subtests. No significant difference in achievement between the students who were enrolled in the math option and those who were not was found, however discrepancies in the data presented by students led the researcher to doubt these results. Multiple regression analysis revealed that the set of independent variables did explain a significant proportion of the variability in achievement. However, even though the findings are statistically significant ($R^2=.123$) they are of little practical significance. Recommendations are given for changes in math content and methods courses for elementary education majors. Test instrument is included.

CHAPTER 1

DEVELOPMENT OF THE PROBLEM

"School mathematics education bears increasing responsibilities in a data-rich era. Mathematics instructional programs should provide individuals access to mathematical ideas and should promote students' abilities to reason analytically. In a society saturated with quantitative information ranging from global climate change data to political polls and consumer reports, such skills will help students to understand, make informed decisions about, and affect their world." (National Council of Teachers of Mathematics, 1998 p.15)

Introduction

In the next 10 years, United States elementary, middle, and secondary schools will hire 2 million new teachers to meet rising enrollment demands and replace an aging teaching force. Half of United States teachers will retire during the same period (National Center for Educational Statistics, 1998). Given these projections and the fact that 21% of US teachers currently have less than a college minor in their principal teaching area (the National Commission on Teaching and America's Future (NCTAF), 1998), the education of preservice teachers must become a national priority. A number of professional associations concerned with teacher education are coordinating their efforts to define the qualities and qualifications essential for the next generation of teachers. These organizations include The National Council for Accreditation of Teacher Education (NCATE), National Council of Teachers of Mathematics (NCTM), American Mathematical Society (AMS), American Statistical Association (ASA), Mathematical

Association of America (MAA), and The International Society for Technology in Education (ISTE). For the first time, these and other stakeholders in teacher education are united in their efforts to raise the standards and expectations of teacher education programs. This research concentrated on an effort currently underway to improve the quality of teaching and learning in one aspect of K-8 mathematics education, statistical data analysis.

Problem

To what degree do students enrolled in the Elementary Education Program at Montana State University – Bozeman acquire and retain the statistical data analysis content required for elementary and middle school as defined by the National Council of Teachers of Mathematics?

Purpose

The purpose of this research was to compare and contrast student statistical data analysis knowledge at different stages of the Montana State University Teacher Education Program. In the mathematics content areas of the Third International Mathematics and Science Study (TIMSS), United States fourth graders slightly exceeded the international average in five of the six areas assessed, including sets of items designed to sample students' ability to do work in data representation, analysis, and probability (NCES, 1997). United States eighth-grade students scored just below the international average in the same areas (NCES, 1996). In a country with a national goal of having the

best-educated children in the world, these results have prompted questions concerning the mathematical competence of United States teachers and the quality of the mathematics curricula in grades K-8. President Clinton's *Call to Action for American Education in the 21st Century* (1997) states that, as a nation, "Strong schools with clear and high standards of achievement and discipline are essential to our children and our society. The United States ranks below average internationally in 8th grade math. We must do better."

"A knowledge of statistics is clearly necessary for students to become informed citizens and intelligent consumers, and statistical reasoning needs to be learned" (NCTM, 1998 p. 70). The National Research Council recommends "Those who would teach mathematics need to learn contemporary mathematics appropriate to the grades they will teach, in a style consistent with the ways in which they will be expected to teach" (1989, p. 64). To be effective, teachers must know their subject matter so thoroughly that they can present it in a challenging, clear, and compelling way (NCATE, 1998).

Graduates of Montana State University's Elementary Education program are eligible to be certified to teach grades K-8. Therefore, it is imperative that as teachers they possess, as a minimum, the knowledge required of eighth grade elementary students. Today's candidate teachers who will become instructors in grades 5-8 often have the same mathematics background as those who will become teachers in grade K-4, yet they are expected to teach more complex content. The additional challenges inherent in the more ambitious curricular material often require them to be more like mathematics specialists than their original training may have prepared them to be. These teachers often have had little exposure to some of the mathematical ideas that ambitious curricula

will require them to teach. Teaching mathematics and statistics in ways that make it understandable by students requires deep, flexible knowledge on the part of the teacher (Silver, 1998).

The National Council of Teachers of Mathematics (NCTM) offers detailed recommendations for teaching statistics in grades K-12 in both *Curriculum and Evaluation Standards for School Mathematics* (1989) and *Principles and Standards for School Mathematics: Discussion Draft* (1998). Mathematical science organizations such as the American Mathematical Association of Two-Year Colleges (AMATYC), the American Mathematical Society (AMS), the American Statistical Association (ASA), the Association for Women in Mathematics (AWM), the Association of State Supervisors of Mathematics (ASSM), the Council of Presidential Awardees in Mathematics (CPAM), the Mathematical Association of America (MAA), and the Society for Industrial and Applied Mathematics (SIAM) promote the vision of school mathematics curriculum as described by NCTM (NCTM, 1989)

The content must be consistent with national mathematics and science standards and convey disciplinary knowledge that relates to student environment and experiences (Friel & Bright, 1997). A growing number of reports and policy statements involving agencies of the federal (NCES, 1998) and state governments (Office of Public Instruction, State of Montana, 1998), professional organizations (NCTM, 1998), and other interested groups (ASA, 1998) call for specific reforms in the content and pedagogy of mathematics education. A National Science Report to the United States Senate (Teacher Retraining, 1997) stated that content must be consistent with national mathematics and science

standards and convey disciplinary knowledge that relates to student environment and experiences. One of the content areas addressed in these reports is data representation, statistical analysis, and statistical graphs. The National Council of Teachers of Mathematics' *Principles and Standards of School Mathematics* (1998) is the most complete and influential presentation on the proposed reforms. With regard to the content focus of this research, the NCTM Standards for Statistics for PreK-8 were treated as the standard by which the statistical data analysis knowledge of elementary education majors at Montana State University was measured.

NCTM Standards for Data Analysis, Statistics and Probability

NCTM's *Principles and Standards for School Mathematics: Discussion Draft* includes 10 Standards. Five of those standards focus on content which address the mathematics that students should know and five standards focus on processes that address ways of acquiring and using that knowledge (See Figure 1).

Figure 1. NCTM Standards for School Mathematics
NCTM Standards for Grades Pre-K-12 (NCTM, 1998)

Content Standards

- Standard 1: Number and Operation
- Standard 2: Patterns, Functions, and Algebra
- Standard 3: Geometry and Spatial Sense
- Standard 4: Measurement
- Standard 5: Data Analysis, Statistics, and Probability

Process Standards

- Standard 6: Problem Solving
- Standard 7: Reasoning and Proof
- Standard 8: Communication
- Standard 9: Connections
- Standard 10: Representation

Standard Five, Data Analysis, Statistics, and Probability, for grades Pre-K-8, states that Mathematics instructional programs should include attention to data analysis, statistics, and probability so that all students –

- ♦ Pose questions and collect, organize, and represent data to answer those questions;
- ♦ Interpret data using methods of exploratory data analysis;
- ♦ Develop and evaluate inferences, predictions, and arguments that are based on data;
- ♦ Understand and apply basic notions of chance and probability (NCTM, 1998)

Specifically, this study dealt only with the following aspect of statistical data analysis knowledge within Standard 5.

- ♦ Interpret data using methods of exploratory data analysis;
 - Find, describe, and interpret mean, median, and mode as measures of the center of a data set; know which measure is best to use in particular situations; and understand how each does and does not represent the data;
 - Describe and interpret the spread of a set of data using tools such as range, interquartile range, and box-and-whisker graphs;
 - Interpret graphical representations of data, including descriptions and discussion of the meaning of the shape and features of the graph, such as symmetry, skewness, and outliers;
 - Analyze associations between variables by comparing the centers, spreads, and graphical representations of related data sets;
 - Examine and interpret relationships between two variables using tools such as scatter plots and approximate lines of best fit. (NCTM, 1998 p.238)

Research Questions

The data obtained in this study were used to characterize the statistical data analysis knowledge of pre-service elementary education majors and to answer the following questions:

1. Was there a difference in the statistical data analysis knowledge among elementary education majors in MATH 130 - Mathematics for Elementary Teachers I, MATH 131 - Mathematics for Elementary Teachers II, EDEL 333 - Teaching Mathematics, and EDEL 410 - Student Teaching?
2. Were demographic factors of gender, age when enrolled in MATH 130, high school mathematics preparation, number of college math and/or statistics classes taken, and/or enrollment in the Elementary Education Math Option related to statistical data analysis knowledge in MATH 130, MATH 131, EDEL 333, and EDEL 410?

Definition of General and Educational Terms

For the purpose of this research, the following definitions were used.

K-8 Certified	Persons with a Bachelor of Science degree in Elementary Education certified by the State of Montana to teach kindergarten through eighth grade in all content areas.
Age Range Sets	1) 25 and younger 2) 26 and older
Non-traditional age	Defined by Montana State University as those students who are older than 25 years old

Four groups to be researched

- 1) Students enrolled in MATH 130 fall semester 1999
- 2) Students enrolled in MATH 131 fall semester 1999
- 3) Students enrolled in EDEL 333 fall semester 1999
- 4) Students enrolled in EDEL 410 fall semester 1999

Math Option

Elementary Education students take 18 additional credits in Mathematics and/or Statistics in place of free electives to enhance their mathematics qualifications. (See Appendix E for specific details.)

Basic High School Mathematics Preparation

Classes up to and including Algebra One. This would include but not be limited to such classes as: Basic Math, General Math, Business Math, Pre-Algebra, Integrated Math I (SIMMS-IM), and Algebra One.

Average High School Mathematics Preparation

Classes including but not limited to Algebra II, Trigonometry, Integrated Math II (SIMMS-IM), Integrated Math III (SIMMS-IM), and Geometry.

Advanced High School Mathematics Preparation

Classes including but not be limited to Pre-Calculus, Calculus, Statistics, Integrated Math IV (SIMMS-IM), Integrated Math V (SIMMS-IM), and Discrete Math.

Definition of Statistical Terms

(Lappan, Fey, Fitzgerald, Friel, & Phillips 1998a, 1998b, 1998c, 1998d; Upshall, 1997; Nichols & Schwartz, 1998; Abelnor, 1979).

Bar graph

A representation of discrete data in which the height of each rectangular bar indicates its value or frequency. Bars are separated from each other to highlight that the data are discrete or 'counted' data.

Box and whisker plot

A graph that shows the distribution of values in a data set. It is constructed from the five-number summary of the data that are minimum value, first quartile, median (second quartile), third quartile, and maximum.

Data analysis	Carefully examining collected data. Thinking about the reliability and validity of the data, conclusions that can be drawn, fairness and appropriateness of the data, and predictions that can be made using the data.
Interquartile range (IQR)	The numerical difference between the first and third quartiles of a distribution. This covers the middle half of the values in the frequency distribution.
Mean	The arithmetic average of the data. It is the center of gravity of the data. It is the value that a set of data would have if all the data were the same value.
Median	The middle of an ordered set of data.
Mode	The most frequently occurring datum.
Normal distribution	A theoretical graph that is continuous and perfectly symmetric on each side of the mean. Frequency values are highest in the middle. The mean, median, and mode represent the same value. Commonly referred to as a bell curve.
Outlier	A value in a data set that is 1.5 IQR less than the Q_1 or 1.5 IQR greater than Q_3 .
Population	The entire collection of people or objects under study.
Probability	The branch of mathematics that focuses on determining the chance of something happening.
Quartile	A partition of an ordered array of data that is equal to one quarter of the data. Each partition is roughly equal in size.
Range	The range is computed by stating the lowest and highest values of the data set.
Sample	A subset of the population, chosen to represent it.
Scatter plot	A graph used to explore the relationship between two variables.

Skewed distribution	A distribution that does not model the normal curve but rather has the greatest frequency of occurrence on either the left or right side of the distribution.
Standard deviation	A measure of the distribution of the data. It measures how far data tend to be from the mean.
Statistics	The branch of mathematics that focuses on collecting and interpreting data.
Stem and leaf plot	A quick way to picture the distribution of values in a data set. The <i>stem</i> of the plot is a vertical number line that represents a range of data values in a specified interval. The <i>leaves</i> are the numbers attached to the particular stem values.
Symmetry	A description of the 'sameness' of portions of a figure.

Summary

This study focused on elementary education majors at Montana State University who were at various stages in their program, specifically students who were enrolled in MATH 130 - Math for Elementary Teachers I, MATH 131 - Math for Elementary Teachers II, EDEL 333 - Teaching Mathematics, or EDEL 410 - Student Teaching. It addressed the need for assessing the Standards-based statistical data analysis knowledge of these prospective elementary teachers. The researcher developed an instrument for assessing what pre-service elementary teachers know, master and retain at various levels of their university studies concerning aspects of the NCTM's statistical data analysis knowledge elementary and middle school children are expected to master.

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

The focus of this study was to determine if there was a difference in statistical data analysis knowledge among elementary education majors at Montana State University who are enrolled in MATH 130 - Math for Elementary Teachers I, MATH 131 - Math for Elementary Teachers II, EDEL 333 - Teaching Mathematics, or EDEL 410 - Student Teaching. The study assessed the NCTM Standards-based statistical data analysis knowledge of these prospective elementary teachers.

The data obtained in this study were used to answer questions about historical and demographic factors associated with statistical data analysis knowledge in MATH 130 - Mathematics for Elementary Teachers I, MATH 131 - Mathematics for Elementary Teachers II, EDEL 333 - Teaching Mathematics, and EDEL 410 - Student Teaching. It also determined to what extent interactions between age at the beginning of MATH 130, gender, level of high school math preparedness, and number of college math and/or statistics class taken were related to statistical data analysis knowledge of pre-service elementary education majors.

Content Knowledge for Teachers

Researchers recognize that teacher behaviors may not be the only factors influencing student achievement. The key questions of research are, "How much knowledge is required for teaching?" and "What kind of knowledge is required for teaching?" Shulman (1987) suggests several "categories of knowledge that underlie the teacher understanding needed to promote comprehension among students." (p. 8).

Shulman states that at a minimum, the categories should include:

- content knowledge;
- general pedagogical knowledge;
- curriculum knowledge;
- pedagogical content knowledge, that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understand;
- knowledge of learners and their characteristics;
- knowledge of educational contexts;
- knowledge of educational ends, purposes, and values, and their philosophical and historical grounds (1987 p. 8)

This study investigated only content knowledge while it is understood that content knowledge alone does not insure good teaching. Leinhardt (1986) found that content knowledge was critical to good teaching. Parsons (1993) supports the theory that a deep subject matter knowledge aids in asking appropriate questions, responding to students, crafting lessons, and providing examples, explanations and demonstrations. While it is recognized that content knowledge is not the only indicator of good teaching, NCTM made a strong statement about the importance of content knowledge - "first and foremost, teaching candidates must have the mathematics content needed for their respective teaching grade levels." ("Start with math," 1999)

"A major goal of teacher education programs is to provide opportunities for prospective teacher to acquire subject matter knowledge" (Adams, 1998 p. 35). Several researchers (Ball, 1990; Even, 1990; Shulman, 1986, 1987; Simon, 1993; Loucks-Horsley, 1999; Steen, 1999a) agree that an individual who plans to teach subject matter to children should have content knowledge and understanding of the content in order to teach that content to school children. Prospective teachers are expected to meet the mathematical needs of children; teachers who have faulty knowledge or misunderstandings are likely to pass that false knowledge or misunderstanding on to the children that they teach (Babbitt & Van Vactor, 1993).

Today's candidate teachers who will become instructors in grades 5-8 often have the same mathematics background as those who will become teachers in grade K-4, yet they are expected to teach more complex content. The additional challenges inherent in the more ambitious curriculum material often require them to be more like mathematics specialists than their original training may have prepared them to be. These teachers often have had little exposure to some of the mathematical ideas that ambitious curricula will require them to teach their students. Teaching mathematics and statistics in ways that make it understandable by students requires deep, flexible knowledge on the part of the teacher (Silver, 1998).

A recent (1998) report published by the National Commission on Teaching and America's Future (NCTAF) reported that what teachers know and can do is the most important influence on what students learn. In this same report, NCTAF assembled research that clearly demonstrated what American parents already believe: Teacher

quality is the factor that matters the most for student learning. The report further reported that the importance of teacher expertise is far outweighs the more modest but generally positive influences of small schools and classes. As a result, the commission recommended more rigorous preparation of teachers still in college. Smith, Peire, Alsalam, Mahoney, Bae and Young (1995) found that

Proficiency in mathematics is an important outcome of education. In an increasingly technological world, the mathematical skills of the nation's workers may be crucial components of economic competitiveness. In addition, knowledge of mathematics is critical for success in science, computing and a number of other related fields of study" (p. 58).

This is supported by the National Council of Teachers of Mathematics in *Principles and Standards for School Mathematics: Discussion Draft* (1998) when they say that to make judgments about tasks, teachers need to know mathematics well beyond the mathematics they teach.

Importance of Statistical Data Analysis Knowledge

Consumers must know how to make critical and informed decisions. Knowledge of statistics will enhance those skills (NCTM, 1989 1998). Students must be able to interpret statistical predictions, (Drier, Dawson, & Garofalo, 1999). Our students will enter a global marketplace that uses quantitative data and graphs to communicate information and to influence decisions at an ever-increasing pace (Shaughnessy, 1992; Smith, Perie, Alsalam, Mahoney, Bae, & Young, 1995). The National Research Council recommends "Those who would teach mathematics need to learn contemporary

mathematics appropriate to the grades they will teach, in a style consistent with the ways in which they will be expected to teach" (1989, p. 64). To be effective, teachers must know their subject matter so thoroughly that they can present it in a challenging, clear, and compelling way (NCATE, 1998). Steen (1999b) concurs when he said, "Nonmathematicians, especially students, harbor nonstandard ideas ("misconceptions") that, "like road accidents," could be avoided through better teaching." (p. 237). Certainly, it follows that student misconceptions could be alleviated or at least minimized if teachers were knowledgeable to begin with.

"A knowledge of statistics is clearly necessary for students to become informed citizens and intelligent consumers, and statistical reasoning needs to be learned" (NCTM, 1998 p. 70). Students must be taught to critically appraise statistics and to be familiar with statistical reasoning including collection, summarization, display and interpretation of data (Scheaffer, 1986). Scheaffer states, "They (students) should learn to become "professional noticers" of the many ways data is used and misused in their world. Students should begin to see statistical reasoning as a process for solving problems through data and quantitative reasoning, and should understand the basic principles involved in the design of a good survey or experiment." "It is important that we actually include probability and statistics in our schools, because people are going to use it and abuse it - perhaps more than any other branch of mathematics - whether or not we teach it." (Shaughnessy, 1992, p. 467).

The goal of statistics education in the elementary school is not that students become statisticians, but that they will be intelligent consumers of statistics as private

citizens (Drier, Dawson, & Garofalo, 1999). "Teachers cannot expect children to pick up en passant the essential features of distributions or the effect of the 'role of large numbers'; these issues need to be discussed fully with the pupils." (Goodchild, 1984 p. 81). Real problems rarely work out as neatly as math problems from texts so students must be taught to interpret data from real world events (Kalman, 1997; Scheaffer, 1986). Students must have opportunities to speculate about when and why people choose to use certain graphs in publications and how pictorial and spatial representations help to communicate relationships (Drier, Dawson, & Garofalo, 1999; Kalman, 1997). Above all we must not assume that because statistical words such as average are in common usage it is properly understood (Goodchild, 1984).

In 1968 a joint commission of the American Statistical Association and the National Council of Teachers of Mathematics developed curricular materials and methods to promote teaching of statistics (Pereira-Mendoza & Dunkels, 1989). But it wasn't until the past ten years that statistics has increased in significance in K-12 education (Scheaffer, 1986). In 1989, the National Council of Teachers of Mathematics published *Curriculum and Evaluation Standards for School Mathematics*. The 'Standards' responded to the call for reform in teaching and learning mathematics. They represented an effort to ensure quality, indicate goals, and promote positive change in mathematics education in grades PreK-12 (NCTM, 1989). NCTM offers detailed recommendations for teaching statistics in grades K-12 in both *Curriculum and Evaluation Standards for School Mathematics* (1989) and *Principles and Standards for School Mathematics: Discussion Draft* (1998). Mathematical science organizations such

as American Mathematical Association of Two-Year Colleges (AMATYC), American Mathematical Society (AMS), American Statistical Association (ASA), Association for Women in Mathematics (AWM), Association of State Supervisors of Mathematics (ASSM), Council of Presidential Awardees in Mathematics (CPAM), Mathematical Association of America (MAA), and Society for Industrial and Applied Mathematics (SIAM) promote the vision of school mathematics as described by NCTM (NCTM, 1989). While the NCTM is recognized as the definitive source for elementary mathematical standards, the National Council for Social Studies (1994), the Geography Education Standards Project (1994), the National Research Council (1996) and The National Council of Teachers of English, together with the International Reading Association (1996) have documented the need for statistical skills within their respective disciplines. The Secretary's Commission on Achieving Necessary Skills (1991) recommends that assessment of statistical skills that are needed for the workplace should take place at the 8th grade level.

NCTM Standards for Data Analysis, Statistics and Probability

NCTM's *Principles and Standards for School Mathematics: Discussion Draft* includes 10 Standards. Five of those standards focus on content which address the mathematics that students should know and five standards focus on process which address ways of acquiring and using that knowledge (See Figure 2).

Standard Five, Data Analysis, Statistics, and Probability, for grades Pre-K-8, states that Mathematics instructional programs should include attention to data analysis, statistics, and probability so that all students –

- ♦ Pose questions and collect, organize, and represent data to answer those questions;
- ♦ Interpret data using methods of exploratory data analysis;
- ♦ Develop and evaluate inferences, predictions, and arguments that are based on data;
- ♦ Understand and apply basic notions of chance and probability (NCTM, 1998)

Figure 2. NCTM Standards for School Mathematics

NCTM Standards for Grades Pre-K-12 (NCTM, 1998)

Content Standards

Standard 1: Number and Operation

Standard 2: Patterns, Functions, and Algebra

Standard 3: Geometry and Spatial Sense

Standard 4: Measurement

Standard 5: Data Analysis, Statistics, and Probability

Process Standards

Standard 6: Problem Solving

Standard 7: Reasoning and Proof

Standard 8: Communication

Standard 9: Connections

Standard 10: Representation

Grades Pre-K-12 are divided into four grade bands. These grade bands are Pre-K-2, 3-5, 6-8, and 9-12. Elaboration of the Data Analysis, Statistics, and Probability Standard for grade bands PreK-2, 3-5, and 6-8 are shown in Figure 3. Since the focus of this study

was statistical data analysis knowledge, the notation and elaboration for the fourth component, which deals exclusively with probability, was not be included.

Figure 3. Standard 5: Data Analysis, Statistics and Probability

Standard 5: Data Analysis, Statistics, and Probability

Mathematics instructional programs should include attention to data analysis, statistics, and probability so that all students -

❖ **pose questions and collect, organize, and represent data to answer those questions;**

In grades pre-K-2, all students should -

- gather data about themselves and their surroundings to answer questions that involve multiple responses
- sort and classify objects and organize data according to attributes of the objects;
- represent data to convey results at a glance using concrete objects, pictures, and numbers. (NCTM, 1998 p 130-131)

In grades 3-5, all students should -

- formulate questions they want to investigate;
- design data investigations to address a question;
- collect data using observations, measurement, surveys, or experiments;
- organize data using tables and graphs (e.g. bar graph, line plot, stem-and-leaf plot, circle graph, and line graph);
- use graphs to analyze data and to present information to an audience;
- compare data representations to determine which aspects of the data they highlight or obscure. (NCTM, 1998 p 181)

In grades 6-8, all students should -

- design experiments and surveys, and consider potential sources of bias in design and data collection;
- recognize types of data (e.g., categorical, count, continuous or measurement) and organize collections of data;
- choose, create and utilize various graphical representations of data (line plots, bar graphs, stem-and-leaf plots, histograms, scatter plots, circle graphs, and box-and-whisker plots) appropriately and effectively (NCTM, 1998 p 238).

❖ **interpret data using methods of exploratory data analysis;**

In grades pre-K-2, all students should -

- describe parts of the data and the data as a whole;
- identify parts of the data with special characteristics, for example the category with the most frequent response. (NCTM, 1998 p 130-131)

In grades 3-5, all students should -

- describe the shape and important features of a set of numerical data, including its range, where the data are concentrated or sparse, and whether there are outliers;
- describe the center of sets of numerical data, first informally, then using the median;
- classify and describe categorical data (e.g., ways we travel to school) in different ways; analyze and compare the information highlighted by different classifications;
- compare related data sets, with emphasis on the range, center, and how the data are distributed;
- propose and justify conclusions based on data;
- formulate questions or hypothesis based on initial data collections, and design further studies to explore them. (NCTM, 1998 p 181)

In grades 6-8, all students should -

- find, describe, and interpret mean, median and mode as measures of the center of a data set; know which measure is best to use in particular situations; and understand how each does and does not represent the data;
- describe and interpret the spread of a set of data using tools such as range, interquartile range, and box-and-whisker graphs;
- interpret graphical representations of data, including descriptions and discussion of the meaning of the shape and features of the graph, such as symmetry, skewness, and outliers;
- analyze associations between variables by comparing the centers, spreads, and graphical representations of related data sets;
- examine and interpret relationships between two variables using tools such as scatter plots and approximate lines of best fit (NCTM, 1998 p 238).

❖ **develop and evaluate inferences, predictions, and arguments that are based on data;**

In grades 3-5, all students should -

- describe how data collection methods can impact the nature of the data set;
- discuss the concept of representativeness of a sample within the context of a particular example (e.g., is the class representative of other fifth-grade classes in our town? In the U.S.? In Canada? Why or why not?);
- compare the data from one sample to other samples and consider why there is variability;
- in simple experiments, infer the structure of the population through drawing repeated samples (with replacement) (NCTM, 1998 p 182)

In grades 6-8, all students should -

- develop conclusions about a characteristic in a population from a well-constructed sample;
- through simulations, develop an understanding about when differences in data may indicate an actual difference in the populations from which the data were

- collected and when the differences may result from natural variation in samples;
- use data to answer the questions that were posed, understand the limitations of these answers, and pose new questions that arise from the data (NCTM, 1998 p 238).

Methods Used in Other Studies

Friel and Bright (1996) developed a written test related to the use and interpretation of graphs. The written instrument was administered as a pre and posttest for seventy-six middle school students. The instrument was developed and scored based on levels of questions (Curcio, 1987) and ability to read graphs (Wainer, 1992). They found that students confuse axes of graphs, have problems with intervals of graphs, and seem to find the measures of center, mean, and median not readily identifiable from the graph. They concluded, "Fundamental to graphicacy are the broader issues of what kinds of questions graphs may be used to answer. By exploring learner's responses to different kinds of questions we gain some knowledge about learners' thinking." (Friel & Bright, 1996. p. 13).

Desmond (1997) developed a written instrument keyed to the NCTM Standards to test geometric content knowledge of eighty-three pre-service teachers during their last semester. She followed up with interviews of seventeen of the students. She found weak abilities on the part of the participants in Standards-based knowledge. There was a weak positive relationship between content and reasoning. In addition, communication skills as outlined by the National Council of Teachers of Mathematics seemed to be related to the geometric content being studied.

Ball (1990) reported on a study of 252 preservice elementary and secondary teachers in five different teacher education programs. This research explored participants' ideas, feelings and understanding about mathematics and about teaching and learning mathematics through the use of scenarios. Content knowledge of the scenarios was developed around different mathematical topics. Questionnaire responses were then followed by interviews. The mathematical understanding these students brought from their high school and college mathematics classes tended to be, "rule bound and thin" (Ball, 1990 p. 124).

Rusch (1997) studied 206 elementary education majors enrolled in a required mathematics education content course at five different post-secondary institutions. The focus of the research was to assess prospective teachers' understanding of place value concepts within a mathematics content course taught by either a constructivist method or a traditional, direct instruction method. A pretest/posttest strategy was used for the assessment instrument that was written specifically for the study. Results suggest that preservice teachers began the course with weak understanding of place value and improved only marginally. There was only a slight difference between the gains made by those students in the constructivist class and those in the traditional direct instruction class.

Professional Standards for Teaching Mathematics (NCTM, 1991) identified specific mathematics content and minimum high school and college mathematics course work requirements for elementary teachers. For teachers of grades K-4, nine semester hours of college coursework in content mathematics is required which would have as a

prerequisite three years of mathematics for college-intending students or an equivalent preparation. For teachers of grades 5-8, NCTM recommends four years of mathematics for college-intending students followed by fifteen hours of college coursework in content mathematics. Dyas (1993) based her research on NCTM's recommendations to study the differences in groups that 1) met both the high school and college requirements, 2) met only the high school requirement, 3) met only the college requirement, or 4) met neither the high school or college requirements. She found that the groups that met high school and college requirements and those that met just high school requirement scored significantly higher than those who did not meet either requirement. This was supported in 1995 by Roberts who tested preservice teachers ($n=103$) on the van Hiele model and explored factors that may be related to their levels of geometric thinking. She found that the mathematics backgrounds of the preservice teachers showed a positive correlation between the number of high school mathematics courses completed by the preservice teachers and their total score on the Van Hiele Geometry Test. Roberts found no significant differences related to gender.

Hutchison (1992) studied the affect of prior subject matter knowledge on learning pedagogical content knowledge in a mathematic methods course. Participants understanding of fractions and pedagogical content knowledge were sampled using two task interviews, a mathematics education biography, three student teaching classroom observations in mathematics, and the classroom observations of the mathematics methods course. The findings suggest that mathematics teacher education programs should reconsider the type of subject matter knowledge required by preservice teachers, since

those with weak prior mathematical content knowledge made few if any gains in pedagogical knowledge because of the need to simultaneously learn both subject matter and pedagogical knowledge.

Smith (1993) compared the conceptual understanding of computational estimation strategies of incoming preservice elementary teachers and those preservice elementary teachers near the completion of the teacher education program. The researcher developed a testing instrument to explore the quantitative mathematics ability as related to computational estimation strategies. The results indicated that for both operations, senior preservice elementary teachers had not acquired more conceptual understanding than those of freshmen. Computation estimation strategies tested were understood approximately the same.

Jones (1995) evaluated preservice middle grades teachers' subject matter knowledge (including beliefs) and pedagogical content knowledge of fractions, decimals, and percents as they progressed through the undergraduate middle grades teacher education program. Participants completed three interviews, two mathematics tests and a questionnaire. Analysis of results indicated that only a small number of participants, both mathematic concentration and non-mathematics concentration, learned contend knowledge of fractions, decimals and percents. The study recommended several changes in the teacher education program to include concepts courses for all students throughout their program.

Lott (1998) conducted a study to examine prospective elementary teachers' knowledge of real numbers, the set of numbers that can be written as a decimal. Lott

administered an open-ended assessment to ninety-three third-year preservice elementary teachers enrolled in three sections of an elementary mathematics methods course. They were asked to provide a drawing model to describe the relationship between given sets of numbers and to write a description of each set. Findings indicated that prospective elementary teachers demonstrated limited subject matter knowledge related to knowledge of real numbers.

Summary

A number of studies (Desmond, Ball, Rusch, Dyas, Roberts, Hutchison, Smith, Jones, and Lott) have found that undergraduates in mathematics related curricula fail to acquire and retain knowledge and skills essential to their disciplines and careers. These studies were conducted in content and methods courses addressing topics that include, geometry, fractions/decimals/percents, place value, estimation, and real numbers. In all cases the students were found to be characteristically below what was expected.

The National Council of Teachers of Mathematics standards are accepted as the basis for PreK-12 education. It is evident that statistical data analysis knowledge is an extremely important skill to function as an informed consumer in our society. Evidence has been presented that these skills are not innate and must be taught. Since we are preparing teachers, it is imperative that we educate them statistically and assess their achievement relative to national goals and standards.

CHAPTER 3

PROCEDURES AND METHODOLOGY

Introduction

This chapter discusses the population and sample, instrumentation, research design, data acquisition, data analysis, and procedures that were used in this study.

Elementary Education Program

The Teacher Education Program at Montana State University offers NCATE accredited Bachelor of Science degrees leading to Montana Teacher Certification for both elementary and secondary education majors. The elementary education component of this program enrolls over 500 students at any given time and graduates approximately 100 students per year. Formal admission to the Teacher Education Program occurs following completion of specified university core classes and other requirements specifically related to the teacher certification process. For most candidates, official admission occurs in their fifth or sixth semester at Montana State University.

The majority of elementary education majors are Montana residents (82%), having entered Montana State University in the fall semester immediately following their graduation from a Montana high school. A meaningful minority (18%), however, are

over the traditional age of 25, often with children of their own. A small minority (2%) are Native American (Johnson, 1999).

During spring term of 1999, the Mathematics Education professors of the Montana State University Department of Mathematical Sciences sought to determine whether student achievement in MATH 130 - Mathematics for Elementary Teachers I was related to one or more demographic factors routinely collected by Montana State University Admissions: ACT composite score; SAT composite score; high school GPA; and/or high school percentile rank. Montana State University institutional researcher Dr. Cel Johnson provided demographic data sets for students enrolled in MATH 130 autumn terms of 1996 and 1997 as part of the database for institutional study. These data were merged with student achievement data from the same courses and delivered to the Montana State University Statistical Consulting Seminar instructor Dr. Jim Robison-Cox for analysis. Under Dr. Robison-Cox's supervision, two master's degree students in the Statistical Consulting Seminar used analysis of variance and logistic regression techniques to analyze the data. The principal finding of this analysis was that there was no useful relationship between the demographic factors and student achievement. As a result, none of the demographic factors had any predictive value relative to student achievement in MATH 130.

Students enrolled in MATH 130 and MATH 131 were typically freshmen or sophomores principally engaged in satisfying university core requirements. These students had declared an elementary education major but had not been formally admitted to the Teacher Education Program.

Students enrolled in EDEL 333 were typically juniors or seniors. They had been formally admitted to the Teacher Education Program with a 2.5 overall GPA, a Basic Skills Core GPA of at least 2.5 and no class in the Basic Skills core with a C- or lower (Montana State University Bulletin, 1998). They also had to present both spontaneous and prepared writing samples as well as demonstrate involvement with children through community services activities. These students were fully engaged in professional development courses at the junior and senior levels and planned to student teach within the next two semesters.

Students enrolled in EDEL 410 had just completed their student teaching, which is part of the capstone course series for their program. Typically, by this time many of them had begun seeking teaching positions. Two of them had already signed teaching contracts for the second semester of the current school year.

Population

The population for this study was all elementary education majors currently enrolled at Montana State University.

Sample

The sample for this study was all Montana State University elementary education majors enrolled in MATH 130 - Mathematics for Elementary Teachers I, MATH 131 -

Mathematics for Elementary Teachers II, EDEL 333 - Teaching Mathematics, or EDEL 410 - Student Teaching during fall semester 1999. Numbers in these groups were:

Figure 4. Student Groups in Study

Group	Number
MATH 130	81
MATH 131	41
EDEL 333	59
EDEL 410	51

Content Focus

For the purpose of this study, research questions were limited to the curriculum standard specifically dealing with statistical data analysis knowledge taken from Standard 5: Data Analysis, Statistics, and Probability of Principles and Standards for School Mathematics: Discussion Draft (NCTM, 1998).

- ♦ Interpret data using methods of exploratory data analysis;
 - Find, describe, and interpret mean, median, and mode as measures of the center of a data set; know which measure is best to use in particular situations; and understand how each does and does not represent the data;
 - Describe and interpret the spread of a set of data using tools such as range, interquartile range, and box-and-whisker graphs;
 - Interpret graphical representations of data, including descriptions and discussion of the meaning of the shape and features of the graph, such as symmetry, skewness, and outliers;
 - Analyze associations between variables by comparing the centers, spreads, and graphical representations of related data sets;

- Examine and interpret relationships between two variables using tools such as scatter plots and approximate lines of best fit. (NCTM, 1998 p.238)

Course Descriptions

Content tested in this study, NCTM Standard 5, Data Analysis, Statistics and Probability, is specifically addressed in MATH 131, the methodology for the standard is presented in EDEL 333, and the application in EDEL 333. Descriptions of the pertinent courses are:

MATH 130 - Math for Elementary Teachers I— A student enrolling in this class must have an ACT math score 23, or a SAT math score of 530, or have successfully completed MATH 103 - Introductory Algebra, or have scored at a level 3 on the university Math Placement Test. MATH 130 is an introduction to problem solving, sets, functions, logic, numeration systems as a mathematical structure, introductory number theory, rational and irrational numbers for prospective elementary school teachers. (4 semester hours)

MATH 131 - Math for Elementary Teachers II— Students must have taken and passed MATH 130 to enroll in MATH 131. MATH 131 covers introductory geometry, constructions, congruence and similarity, concepts of measurement, coordinate geometry, simple and complex experiments, odds, conditional probability, expected value, simulation, organizing and picturing information, collecting and analyzing data, and computer application for prospective elementary school teachers. (4 semester hours)

EDEL 333 - Teaching Mathematics — To enroll in EDEL 333, students must have taken and passed EDCI 360 - Foundations of Assessment, MATH 131 and be in good standing in Teacher Education Program. EDEL 333 covers math methods and materials for the prospective elementary teacher. Classroom organization, operation, management, applied technology, evaluation and current theory are also key components of the class. (3 semester hours)

EDEL 410 - Student Teaching — Students must have Senior standing, have completed of all required EDEL methods courses and be in good standing in Teacher Education Program. Student Teaching involves observation and teaching in a K-8 classroom setting; preparation and delivery of lesson plans. The student teaching experience occurs under the supervision of experienced teachers and MSU staff supervisors. (5-12 semester hours)

Independent Variables

For the purposes of this study, the independent variable was the group (MATH 130 - Mathematics for Elementary Teachers I, MATH 131 - Mathematics for Elementary Teachers II, EDEL 333 - Teaching Mathematics, EDEL 410 - Student Teaching) in which elementary education students were enrolled during Fall Semester 1999. Other factors were gender, age, high school mathematics preparation, number of college math and/or statistics classes taken, and enrollment in the elementary education math option.

Dependent Variables

Dependent variables were overall achievement; achievement when finding, describing and interpreting mean, median and mode; achievement in interpreting the spread of a set of data; achievement in understanding the meaning of the shape and features of a graph; achievement in comparing centers, spreads, and graphical representations of related data sets; and achievement in using scatter plots and lines of best fit

Hypotheses

Specific Research questions and hypotheses tested are as follows.

1. Group and gender will not significantly interact on each of the following dependent variables: a) overall achievement, b) achievement when finding, describing and interpreting mean, median and mode, c) achievement in interpreting the spread of a set of data, d) achievement in understanding the meaning of the shape and features of a graph, e) achievement in comparing centers, spreads, and graphical representations of related data sets, and f) achievement in using scatter plots and lines of best fit. If a significant interaction was found simple effects analyses were performed. In the case where the null hypothesis of interaction was retained the following main effects hypotheses were tested.

- 1.1 There is no significant difference between the mean of all males and the mean of all females in: a) overall achievement, b) achievement when finding,

describing and interpreting mean, median and mode, c) achievement in interpreting the spread of a set of data, d) achievement in understanding the meaning of the shape and features of a graph, e) achievement in comparing centers, spreads, and graphical representations of related data sets, and f) achievement in using scatter plots and lines of best fit.

1.2 There is no significant difference among the means of the four groups in:

a) overall achievement, b) achievement when finding, describing and interpreting mean, median and mode, c) achievement in interpreting the spread of a set of data, d) achievement in understanding the meaning of the shape and features of a graph, e) achievement in comparing centers, spreads, and graphical representations of related data sets, and f) achievement in using scatter plots and lines of best fit.

When a significant main effect was detected the Newman-Kuels post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses.

2. Group and age will not significantly interact on each of the following dependent variables: a) overall achievement, b) achievement when finding, describing and interpreting mean, median and mode, c) achievement in interpreting the spread of a set of data, d) achievement in understanding the meaning of the shape and features of a graph, e) achievement in comparing centers, spreads, and graphical representations of related data sets, and f) achievement in using scatter plots and lines of best fit. In the case where the null hypothesis of interaction was retained the following main effects hypotheses were tested.

- 2.1 There is no significant difference among the means of traditional age students and non traditional age students in: a) overall achievement, b) achievement when finding, describing and interpreting mean, median and mode, c) achievement in interpreting the spread of a set of data, d) achievement in understanding the meaning of the shape and features of a graph, e) achievement in comparing centers, spreads, and graphical representations of related data sets, and f) achievement in using scatter plots and lines of best fit.

When a significant main effect was detected the Newman-Kuels post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses.

3. Group and degree of high school mathematics preparation will not significantly interact on each of the following dependent variables: a) overall achievement, b) achievement when finding, describing and interpreting mean, median and mode, c) achievement in interpreting the spread of a set of data, d) achievement in understanding the meaning of the shape and features of a graph, e) achievement in comparing centers, spreads, and graphical representations of related data sets, and f) achievement in using scatter plots and lines of best fit. In the case where the null hypothesis of interaction was retained the following main effects hypotheses were tested.

- 3.1 There is no significant difference among the means of all students with different high school mathematics preparation in: a) overall achievement, b) achievement when finding, describing and interpreting mean, median and

mode, c) achievement in interpreting the spread of a set of data, d) achievement in understanding the meaning of the shape and features of a graph, e) achievement in comparing centers, spreads, and graphical representations of related data sets, and f) achievement in using scatter plots and lines of best fit..

When a significant main effect was detected the Newman-Kuels post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses.

4. Group and number of college math and/or statistics classes taken will not significantly interact on each of the following dependent variables: a) overall achievement, b) achievement when finding, describing and interpreting mean, median and mode, c) achievement in interpreting the spread of a set of data, d) achievement in understanding the meaning of the shape and features of a graph, e) achievement in comparing centers, spreads, and graphical representations of related data sets, and f) achievement in using scatter plots and lines of best fit. In the case where the null hypothesis of interaction was retained the following main effects hypotheses were tested.

- 4.1 There is no significant difference among the mean of number of college math and/or statistics classes taken in: a) overall achievement, b) achievement when finding, describing and interpreting mean, median and mode, c) achievement in interpreting the spread of a set of data, d) achievement in understanding the meaning of the shape and features of a graph, e) achievement in comparing centers, spreads, and graphical representations

of related data sets, and f) achievement in using scatter plots and lines of best fit.

When a significant main effect was detected the Newman-Kuels post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses.

5. Group and whether or not the student is in the Elementary Education Program math option will not significantly interact on each of the following dependent variables:
 - a) overall achievement, b) achievement when finding, describing and interpreting mean, median and mode, c) achievement in interpreting the spread of a set of data, d) achievement in understanding the meaning of the shape and features of a graph, e) achievement in comparing centers, spreads, and graphical representations of related data sets, and f) achievement in using scatter plots and lines of best fit. If there had not been at least 10 students in each EDEL 333 and EDEL 410 who had taken more than MATH 130 and MATH 131 and were not in the math option this dependent variable would not have been used for statistical analysis. In the case where the null hypothesis of interaction was retained the following main effects hypotheses were tested.

- 5.1 There is no significant difference between the mean of all math option enrollees and the mean of all non-math option enrollees in:
 - a) overall achievement, b) achievement when finding, describing and interpreting mean, median and mode, c) achievement in interpreting the spread of a set of data, d) achievement in understanding the meaning of the shape and features of a graph, e) achievement in comparing centers, spreads, and graphical

representations of related data sets, and f) achievement in using scatter plots and lines of best fit.

When a significant main effect was detected the Newman-Kuels post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses.

6. Grade taught during student teaching and whether or not student taught math while student teaching will not significantly interact on each of the following dependent variables: a) overall achievement, b) achievement when finding, describing and interpreting mean, median and mode, c) achievement in interpreting the spread of a set of data, d) achievement in understanding the meaning of the shape and features of a graph, e) achievement in comparing centers, spreads, and graphical representations of related data sets, and f) achievement in using scatter plots and lines of best fit.

- 6.1 There is no significant difference between the mean of PreK-2 student teachers, 3-5 student teachers and 6-8 student teachers in: a) overall achievement, b) achievement when finding, describing and interpreting mean, median and mode, c) achievement in interpreting the spread of a set of data, d) achievement in understanding the meaning of the shape and features of a graph, e) achievement in comparing centers, spreads, and graphical representations of related data sets, and f) achievement in using scatter plots and lines of best fit.

- 6.2 There is no significant difference between the mean of the student teachers who taught math and those who did not teach math during student teaching in:
 - a) overall achievement, b) achievement when finding, describing and interpreting b) mean, median and mode, c) achievement in interpreting the

spread of a set of data, d) achievement in understanding the meaning of the shape and features of a graph, e) achievement in comparing centers, spreads, and graphical representations of related data sets, and f) achievement in using scatter plots and lines of best fit.

7. The set of independent variables (gender, age when enrolled in MATH 130, number of high school math classes taken and passed, number of college math classes taken and passed, number of college statistics classes taken and passed and whether or not the student is enrolled in Elementary Education program math option) do not explain a significant proportion of the variability in: a) overall achievement, b) achievement when finding, describing and interpreting mean, median and mode, c) achievement in interpreting the spread of a set of data, d) achievement in understanding the meaning of the shape and features of a graph, e) achievement in comparing centers, spreads, and graphical representations of related data sets, and f) achievement in using scatter plots and lines of best fit.

Instrument

A paper and pencil instrument and scoring rubric for evaluating the achievement of Montana State University elementary education majors relative to these specific NCTM data analysis standards was developed (See Appendix A) using commonly accepted procedures (Desmond, 1997, Bell, 1995, Wilburne, 1997). The specific components of Standard 5 that were tested are shown in Figure 5. The Table of

Specifications found in Figure 6 summarizes the relationship between the specified content strands from the NCTM Standards for Statistics for PreK-8 and the research instrument developed for this study.

Figure 5. Standard 5 of Principles and Standards for School Mathematics: Discussion Draft

-
- Find, describe, and interpret mean, median and mode as measures of the center of a data set; know which measure is best to use in particular situations; and understand how each does and does not represent the data;
 - Describe and interpret the spread of a set of data using tools such as range, interquartile range, and box-and-whisker graphs;
 - Interpret graphical representations of data, including descriptions and discussion of the meaning of the shape and features of the graph, such as symmetry, skewness, and outliers;
 - Analyze associations between variables by comparing the centers, spreads, and graphical representations of related data sets;
 - Examine and interpret relationships between two variables using tools such as scatter plots and approximate lines of best fit

Validation

The research instrument was validated by a team of math educators and statisticians with suitable professional qualifications and experience: Dr. Miguel Paz, Statistician, Department of Mathematical Sciences, Montana State University; Dr. Jeff Banfield, Statistician, Department of Mathematical Sciences, Montana State University; Dr. Maurice Burke, Mathematics Educator, Department of Mathematical Sciences, Montana State University; Dr. Lyle Andersen, Mathematics Educator, Department of Mathematical Sciences, Montana State University; and Dr. Ted Hodgson, Mathematics Educator, Department of Mathematical Sciences, Montana State University. See Appendix C for letter to mathematicians and statisticians.

Dr. Paz, Dr. Hodgson, and Dr. Burke independently reviewed the instrument and scoring rubric, rated each item as acceptable or unacceptable in both form and content, and made recommendations for correcting and/or supplementing the list of test items. The researcher reviewed these recommendations to identify all necessary changes in either form or content. After revisions were made, they were sent to the team of math educators and statisticians for a second review. Dr. Paz, Dr. Hodgson, Dr. Burke, Dr. Andersen, and Dr. Banfield were given the final test with a blank copy of the Table of Specifications (See Appendix D). They were asked to mark the table of specifications to determine content validity in relation to the goals. Their determinations of content are shown in Figure 6.

Reliability

During the summer session of 1999, a pilot study was conducted. Arrangements were made with the MATH 130 - Mathematics for Elementary Teachers I, MATH 131 - Mathematics for Elementary Teachers II, and EDEL 325 - Teaching Science course supervisors to conduct a reliability check of the instrument. The enrollment in each of the mathematics courses was 11 students. The enrollment in the Science education class was 35. The total number tested in the pilot was 57. The instrument has four demographic items (1-4), twenty-eight multiple-choice items (5-32) and seven short answer items (33-39). The multiple-choice items (5-32) were scored by the Testing Center at Montana State University. Since there was one test to be given only one time,

Figure 6. Table of Specifications with Content Validation

- A. Find, describe, and interpret mean, median and mode as measures of the center of a data set; know which measure is best to use in particular situations; and understand how each does and does not represent the data;
- B. Describe and interpret the spread of a set of data using tools such as range, inter-quartile range, and box-and-whisker graphs;
- C. Interpret graphical representations of data, including descriptions and discussion of the meaning of the shape and features of the graph, such as symmetry, skewness, and outliers;
- D. Analyze associations between variables by comparing the centers, spreads, and graphical representations of related data sets;
- E. Examine and interpret relationships between two variables using tools such as scatter plots and approximate lines of best fit.

#	A	B	C	D	E
5		5			
6	5				
7	5				
8	4			1	
9	4			1	
10	4			1	
11	5				
12	5				
13	5				
14			1		4
15			1		4
16	5				
17		5			
18		5			
19	4		1		
20		4	1		
21		4	1		
22					5
23					5
24					5

#	A	B	C	D	E
25			5		
26			4	1	
27			4	1	
28			4	1	
29			2	3	
30			1	3	1
31			3		2
32				2	3
33				2	3
34	3		1		
35				2	3
36					5
37			3		2
38			5		

the best method for estimating reliability was the Kuder-Richardson internal reliability coefficient (Gay, 1996). A Kuder-Richardson of .79 was obtained. To estimate the

scorer reliability for the short answer items (33-39), the researcher scored and re-scored (blind) all the short answer answers on the tests with a period of three weeks between scoring. A Pearson r correlation was used to determine scorer reliability. The reliability coefficient was .93 overall. See Appendix B for specific scoring rubrics.

Research Design

This study employed a non-experimental research design involving intact groups (Kerlinger, 1986). The purpose of the research was to compare and contrast student statistical data analysis knowledge at different stages of the Montana State University Teacher Education Program. As defined by accreditation documents and procedures, the Montana State University Elementary Teacher Education Program was stable in content and format. Furthermore, the characteristics of entering students are stable from year to year. As a result, this study assumed that student characteristics could be sampled simultaneously at different stages of the Teacher Education Program without concern that programmatic effects will be obscured by year-to-year variations in the student population.

Tests T₁, T₂, T₃, and T₄, were made at four stages of the Teacher Education Program: MATH 130 - Mathematics for Elementary Teachers I, MATH 131 - Mathematics for Elementary Teachers II, EDEL 333 - Teaching Mathematics, and EDEL 410 - Student Teaching. The research instrument was administered near the beginning of MATH 130 and at the end of each of the other courses. One 50-minute class period

was allocated for testing, but students were allowed more time if necessary. Calculators were allowed.

Figure 7. Scheduled Testing

T ₁	T ₂	T ₃	T ₄
September 3, 1999	December 1, 1999	December 9, 1999	December 7, 1999
MATH 130	MATH 131	EDEL 333	EDEL 410

Data collection for the study was collected during fall semester 1999. Students in MATH 130 were tested in early September. Students in MATH 131, EDEL 333 and EDEL 410 were tested in early December.

Data Analysis Strategy

Two-way analyses of variance were done to see if there were differences in understanding of statistical data analysis by elementary education majors at the end of MATH 130 - Mathematics for Elementary Teachers I, MATH 131 - Mathematics for Elementary Teachers II, EDEL 333 - Teaching Mathematics, and EDEL 410 - Student Teaching with respect to 1) Overall achievement, 2) Achievement when finding, describing and interpreting mean median and mode, 3) Achievement in interpreting the spread of a set of data, 4) Achievement in understanding the meaning of the shape and features of a graph, 5) Achievement in comparing centers, spreads, and graphical representations of related data sets, and 6) Achievement in using scatter plots and lines of best fit. When it was determined that a difference in understanding of statistical data analysis existed, a series of planned pair-wise comparisons was used to determine where performances differed. Simple effects analysis had been planned to interpret interaction

findings. Since there was no evidence of interaction, no simple effects analyses were performed.

Multiple regressions were done to determine if demographic factors of gender, age when enrolled in MATH 130, number of high school math classes taken and passed, number of college math classes taken and passed, number of college statistics classes taken and passed and whether or not the student is enrolled in Elementary Education program math option are associated with understanding statistical data analysis in MATH 130 - Mathematics for Elementary Teachers I, MATH 131 - Mathematics for Elementary Teachers II, EDEL 333 - Teaching Mathematics, and EDEL 410 - Student Teaching with respect to 1) Overall achievement, 2) Achievement when finding, describing and interpreting mean median and mode, 3) Achievement in interpreting the spread of a set of data, 4) Achievement in understanding the meaning of the shape and features of a graph, 5) Achievement in comparing centers, spreads, and graphical representations of related data sets, and 6) Achievement in using scatter plots and lines of best fit.

Alpha level

An alpha level of 0.05 was set before collection of data took place. This level was adopted instead of a more conservative 0.01 because it is hard to imagine any harm that could be done to the students by advocating increased instruction in statistical data analysis even if no measurable advantages existed. That is to say a Type I error (rejecting the null even though it is true) could not possibly have serious negative effects. This researcher was quite concerned about the possibility of making a Type II error

(failing to reject the null even though it is false). Doing so would mean that the university missed the opportunity to add statistical data analysis to the mathematics classes and thus help students be better prepared to be elementary teachers.

Limitations

1. One limitation of the study was that students were not randomly assigned to Blocks A and B within the Elementary Education Program. Student placement was determined by an assortment of factors including morning or afternoon requirements, necessity of a summer session of classes, and with a priority given to second semester students.
2. Another limitation of the study was that not all of the students in the study took their mathematics content classes at Montana State University. The students who did take MATH 130 - Mathematics for Elementary Teachers I and MATH 131 - Mathematics for Elementary Teachers II at Montana State University took them during different semesters with a variety of instructors. The background and experience of instructors were not exactly the same. Some instructors were faculty and some were graduate teaching assistants with little or no experience in elementary mathematics education.

Delimitations

1. The variables in this study (group membership, age, gender, level of high school math preparation, and number of college math and/or statistics classes taken) may not be the only ones that affect statistical data analysis knowledge, nor may they be the most significant variables.
2. The study was conducted during the fall semester of 1999 at Montana State University - Bozeman.
3. The study was limited to students enrolled in MATH 130 - Mathematics for Elementary Teachers I, MATH 131 - Mathematics for Elementary Teachers II, EDEL 333 - Teaching Mathematics, and EDEL 410 - Student Teaching, at Montana State University during fall semester 1999,

Summary

The purpose of the study was to determine if students enrolled in the Elementary Education Program at Montana State University acquire and retain the statistical data analysis content required of elementary school teachers. Data was gathered from students at four different stages of the elementary education program at Montana State University. Multiple regression and ANOVA were used to determine if changes in achievement occurred and also if demographics made a difference in achievement.

CHAPTER 4

DATA ANALYSES AND FINDINGS

Introduction

This chapter is arranged to show data gathered and statistical results related to the specific hypotheses stated in this study. Hypotheses one through six were tested with a Two-Way ANOVA. Hypothesis seven was tested through Multiple Regression analysis. See Appendix F for complete tables of means for two-way ANOVA analyses.

Two-Way ANOVA Analyses

Hypothesis 1A

Hypothesis 1A was retained. Group and gender did not significantly interact on overall achievement. The p-value for interaction exceeded 0.05.

Hypothesis 1A.1

Hypothesis 1A.1 was retained. There was no significant difference between the mean of all males and the mean of all females in overall achievement. The mean for all males was 22.33 and the mean for all females was 22.35. The p-value was greater than 0.05.

Table 1. Summary of Analysis of Variance Comparing Effect of Group Membership and Gender on Achievement

Source	df	MS	F-ratio	P-value
Total test Achievement (Hyp. 1A)				
Group	3	226.472	12.571	.000
Gender	1	.000647	.000	.995
Group*Gender	3	32.882	1.825	.143
Error	224	18.015		
Sub test 1 Achievement (Hyp. 1B)				
Group	3	57.053	10.417	.000
Gender	1	1.872	.342	.559
Group*Gender	3	7.9333	1.338	.230
Error	224	5.477		
Sub test 2 Achievement (Hyp. 1C)				
Group	3	15.533	14.186	.000
Gender	1	.120	.109	.741
Group*Gender	3	.539	.492	.688
Error	224	1.095		
Sub test 3 Achievement (Hyp. 1D)				
Group	3	5.889	6.355	.000
Gender	1	1.505	1.625	.204
Group*Gender	3	1.010	1.090	.354
Error	224	.927		
Sub test 4 Achievement (Hyp. 1E)				
Group	3	1.626	2.086	.103
Gender	1	.02175	.028	.867
Group*Gender	3	.612	.786	.503
Error	224	.779		
Sub test 5 Achievement (Hyp. 1F)				
Group	3	8.871	3.655	.013
Gender	1	.230	.095	.758
Group*Gender	3	2.685	1.106	.347
Error	224	2.427		

Hypothesis 1A.2

Hypothesis 1A.2 was rejected. There was a significant difference among the means of the four groups in overall achievement. The means for the four groups were 19.91 (MATH 130), 25.52 (MATH 131), 24.11 (EDEL 333) and 21.65 (EDEL 410). The p-value was < 0.05 .

A Newman-Keuls post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses. The mean of MATH 130 was significantly less than the means of MATH 131, EDEL 333 and EDEL 410. The mean of EDEL 410 was significantly less than the means of MATH 131 and EDEL 333.

Hypothesis 1B

Hypothesis 1B was retained. Group and gender did not significantly interact on achievement when finding, describing and interpreting mean, median and mode. The p-value for interaction exceeded 0.05.

Hypothesis 1B.1

Hypothesis 1B.1 was retained. There was no significant difference between the mean of all males and the mean of all females in achievement when finding, describing and interpreting mean, median and mode. The mean of all males was 6.08 and the mean for all females was 6.38. The p-value was greater than 0.05.

Hypothesis 1B.2

Hypothesis 1B.2 was rejected. There was a significant difference among the means of the four groups in achievement when finding, describing and interpreting mean, median and mode. The means for the four groups were 5.16 (MATH 130), 8.07 (MATH 131), 6.91 (EDEL 333) and 6.13 (EDEL 410). The p-value was less than 0.05.

A Newman-Keuls post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses. The mean for MATH 130 was significantly lower than the means of MATH 131, EDEL 410 and EDEL 333. The means of EDEL 410 and EDEL 333 were both significantly lower than the mean of MATH 131.

Hypothesis 1C

Hypothesis 1C was retained. Group and gender did not significantly interact on achievement in interpreting the spread of a set of data. The p-value for interaction exceeded 0.05.

Hypothesis 1C.1

Hypothesis 1C.1 was retained. There was no significant difference between the mean of all males and the mean of all females in achievement in interpreting the spread of a set of data. The mean for all males was 3.28 and the mean for all females was 3.42. The p-value exceeded 0.05.

Hypothesis 1C.2

Hypothesis 1C.2 was rejected. There was a significant difference among the means of the four groups in achievement in interpreting the spread of a set of data. The means for the four groups were 2.70 (MATH 130), 4.12 (MATH 131), 3.88 (EDEL 333) and 3.35 (EDEL 410). The p-value was less than 0.05.

A Newman-Keuls post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses. The mean of MATH 130 was significantly less than the means of MATH 131, EDEL 333 and EDEL 410. The mean of EDEL 410 was significantly less than the means of MATH 131 and EDEL 333.

Hypothesis 1D

Hypothesis 1D was retained. Group and gender did not significantly interact on achievement in understanding the meaning of the shape and features of a graph. The p-value for interaction exceeded 0.05.

Hypothesis 1D.1

Hypothesis 1D.1 was retained. There was no significant difference between the mean of all males and the mean of all females in achievement in understanding the meaning of the shape and features of a graph. The mean for all males was 5.08 and the mean for all females was 4.92. The p-value was greater than 0.05.

Hypothesis 1D.2

Hypothesis 1D.2 was rejected. There was a significant difference among the means of the four groups in achievement in understanding the meaning of the shape and features of a graph. The means for the four groups were 4.62 (MATH 130), 5.39 (MATH 131), 5.29 (EDEL 333) and 4.71 (EDEL 410). The p-value was less than 0.05.

A Newman-Keuls post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses. The means of MATH 130 and EDEL 410 were both less than the means of EDEL 333 and MATH 131.

Hypothesis 1E

Hypothesis 1E was retained. Group and gender did not significantly interact on achievement in comparing centers, spreads, and graphical representations of related data sets. The p-value for interaction exceeded 0.05.

Hypothesis 1E.1

Hypothesis 1E.1 was retained. There was no significant difference between the mean of all males and the mean of all females in achievement in comparing centers, spreads, and graphical representations of related data sets. The mean of all males was 2.97 and the mean for all females was 3.01. The p-value was greater than 0.05.

Hypothesis 1E.2

Hypothesis 1E.2 was retained. There was no significant difference among the means of the four groups in achievement in comparing centers, spreads, and graphical representations of related data sets. The means for the four groups were 2.78(MATH 130), 2.95 (MATH 131), 3.12 (EDEL 333) and 3.12 (EDEL 410). The p-value was greater than 0.05.

Hypothesis 1F

Hypothesis 1F was retained. Group and gender did not significantly interact on achievement in using scatter plots and lines of best fit. The p-value for interaction exceeded 0.05.

Hypothesis 1F.1

Hypothesis 1F.1 was retained. There was not a significant difference between the mean of all males and the mean of all females in achievement in using scatter plots and lines of best fit. The p-value exceeded 0.05.

Hypothesis 1F.2

Hypothesis 1F.2 was rejected. There was a significant among the means of the four groups in achievement in using scatter plots and lines of best fit. The means for the four groups were 7.26 (MATH 130), 8.10(MATH 131), 8.10(EDEL 333) and 7.25 (EDEL 410). The p-value was less than 0.05.

A Newman-Keuls post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses. The means of MATH 130 and EDEL 410 were both less than the means of EDEL 333 and MATH 131.

Table 2. Summary of Analysis of Variance Comparing Effect of Group Membership and Age on Achievement

Source	df	MS	F-ratio	P-value
Overall Achievement (Hyp. 2A)				
Group	3	126.079	6.876	.000
Age	1	.154	.008	.927
Group*Age	3	7.172	.391	.760
Error	224	18.335		
Sub test 1 Achievement (Hyp. 2B)				
Group	3	22.190	4.030	.008
Age	1	.08174	.015	.903
Group*Age	3	5.845	1.062	.366
Error	224	5.506		
Sub test 2 Achievement (Hyp. 2C)				
Group	3	13.644	12.612	.000
Age	1	.05664	.052	.819
Group*Age	3	1.420	1.313	.271
Error	224	1.082		
Sub test 3 Achievement (Hyp. 2D)				
Group	3	4.803	5.127	.002
Age	1	.694	.741	.390
Group*Age	3	.483	.516	.672
Error	224	.937		
Sub test 4 Achievement (Hyp. 2E)				
Group	3	1.238	1.573	.197
Age	1	.01111	.014	.906
Group*Age	3	.02569	.033	.992
Error	224	.787		
Sub test 5 Achievement (Hyp. 2F)				
Group	3	7.963	3.252	.023
Age	1	.374	.153	.696
Group*Age	3	.820	.335	.800
Error	224	2.449		

Hypothesis 2A

Hypothesis 2A was retained. Group and age did not significantly interact on overall achievement. The p-value exceeded 0.05.

Hypothesis 2A.1

Hypothesis 2A.1 was retained. There was no significant difference between the mean of all traditional age students and the mean of all nontraditional age students in overall achievement. The mean of traditional age students was 22.41 and the mean of nontraditional age students was 21.7619. The p-value exceeded 0.05.

Hypothesis 2B

Hypothesis 2B was retained. Group and age did not significantly interact on achievement when finding, describing and interpreting mean, median and mode. The p-value was greater than 0.05.

Hypothesis 2B.1

Hypothesis 2B.1 was retained. There was no significant difference between the mean of all traditional age students and the mean of all nontraditional age students in achievement when finding, describing and interpreting mean, median and mode. The mean of traditional age students was 6.37 and the mean of nontraditional age students was 6.00. The p-value exceeded 0.05.

Hypothesis 2C

Hypothesis 2C was retained. Group and age did not significantly interact on achievement in interpreting the spread of a set of data. The p-value exceeded 0.05.

Hypothesis 2C.1

Hypothesis 2C.1 was retained. There was no significant difference between the mean of all traditional age students and the mean of all nontraditional age students in achievement in interpreting the spread of a set of data. The mean of traditional age

students was 3.41 and the mean of nontraditional age students was 3.24. The p-value exceeded 0.05.

Hypothesis 2D

Hypothesis 2D was retained. Group and age did not significantly interact on achievement in understanding the meaning of the shape and features of a graph. The p-value exceeded 0.05.

Hypothesis 2D.1

Hypothesis 2D.1 was retained. There was no significant difference between the mean of all traditional age students and the mean of all nontraditional age students in achievement in understanding the meaning of the shape and features of a graph. The mean of traditional age students was 4.93 and the mean of nontraditional age students was 5.05. The p-value exceeded 0.05.

Hypothesis 2E

Hypothesis 2E was retained. Group and age did not significantly interact on achievement in comparing centers, spreads, and graphical representations of related data sets. The p-value exceeded 0.05.

Hypothesis 2E.1

Hypothesis 2E.1 was retained. There was no significant difference between the mean of all traditional age students and the mean of all nontraditional age students in achievement in comparing centers, spreads, and graphical representations of related data sets. The mean of traditional age students was 3.00 and the mean of nontraditional age students was 3.05. The p-value exceeded 0.05.

Hypothesis 2F

Hypothesis 2F was retained. Group and age did not significantly interact on achievement in using scatter plots and lines of best fit. The p-value exceeded 0.05.

Hypothesis 2F.1

Hypothesis 2F.1 was retained. There was no significant difference between the mean of all traditional age students and the mean of all nontraditional age students in achievement in using scatter plots and lines of best fit. The mean of traditional age students was 7.64 and the mean of nontraditional age students was 7.38. The p-value exceeded 0.05.

Table 3. Summary of Analysis of Variance Comparing Effect of Group Membership and Degree of High School Mathematics Preparation on Achievement

Source	df	MS	F-ratio	P-value
Overall Achievement (Hyp. 3A)				
Group	3	225.668	13.070	.000
HS preparation	2	92.662	5.367	.005
Group*HS preparation	6	14.574	.844	.537
Error	220	17.265		
Sub test 1 Achievement (Hyp. 3B)				
Group	3	50.445	9.336	.000
HS preparation	2	17.465	3.232	.041
Group*HS preparation	6	3.526	.653	.688
Error	220	5.404		
Sub test 2 Achievement (Hyp. 3C)				
Group	3	11.764	11.220	.000
HS preparation	2	4.450	4.244	.016
Group*HS preparation	6	.813	.775	.590
Error	220	1.048		
Sub test 3 Achievement (Hyp. 3D)				
Group	3	4.442	4.827	.003
HS preparation	2	3.114	3.384	.036
Group*HS preparation	6	.357	.388	.886
Error	220	.920		
Sub test 4 Achievement (Hyp. 3E)				
Group	3	2.907	3.771	.011
HS preparation	2	1.186	1.539	.217
Group*HS preparation	6	.611	.793	.577
Error	220	.771		
Sub test 5 Achievement (Hyp. 3F)				
Group	3	11.827	4.966	.002
HS preparation	2	3.660	1.537	.217
Group*HS preparation	6	2.203	.925	.478
Error	220	2.382		

Hypothesis 3A

Hypothesis 3A was retained. Group and degree of high school mathematics preparation did not significantly interact on overall achievement. The p-value exceeded 0.05.

Hypothesis 3A.1

Hypothesis 3A.1 was rejected. There was a significant difference among the means of basic, average and advanced degree of high school mathematics preparation in overall achievement. The mean of students with basic high school preparation was 20.53. The mean of students with average high school preparation was 21.60 and the mean of students with advanced high school preparation was 23.5. The p-value was less than 0.05.

A Newman-Keuls post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses. The mean of students with basic high school preparation was significantly lower than both the means of students with average high school preparation and those students with advanced high school preparation.

Hypothesis 3B

Hypothesis 3B was retained. Group and degree of high school mathematics preparation did not significantly interact on achievement when finding, describing and interpreting mean, median and mode. The p-value exceeded 0.05.

Hypothesis 3B.1

Hypothesis 3B.1 was rejected. There was a significant difference among the mean of basic, average and advanced degree of high school mathematics preparation in achievement when finding, describing and interpreting mean, median and mode. The mean of students with basic high school preparation was 5.67. The mean of students with average high school preparation was 6.01 and the mean of students with advanced high school preparation was 6.83. The p-value was less than 0.05.

A Newman-Keuls post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses. No pair wise comparisons showed a significant difference in means.

Hypothesis 3C

Hypothesis 3C was retained. Group and degree of high school mathematics preparation did not significantly interact on achievement in interpreting the spread of a set of data. The p-value exceeded 0.05.

Hypothesis 3C.1

Hypothesis 3C.1 was rejected. There was a significant difference among the means of basic, average and advanced degree of high school mathematics preparation in achievement in interpreting the spread of a set of data. The mean of students with basic high school preparation was 3.07. The mean of students with average high school preparation was 3.24 and the mean of students with advanced high school preparation was 3.64. The p-value was less than 0.05.

A Newman-Keuls post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses. The mean of students with basic high school preparation was significantly lower than both the means of students with average high school preparation and those students with advanced high school preparation.

Hypothesis 3D

Hypothesis 3D was retained. Group and degree of high school mathematics preparation did not significantly interact on achievement in understanding the meaning of the shape and features of a graph. The p-value exceeded 0.05.

Hypothesis 3D.1

Hypothesis 3D.1 was rejected. There was a significant difference among the means of basic, average and advanced degree of high school mathematics preparation in achievement in understanding the meaning of the shape and features of a graph. The mean of students with basic high school preparation was 4.80. The mean of students with average high school preparation was 4.79 and the mean of students with advanced high school preparation was 5.15. The p-value was less than 0.05.

A Newman-Keuls post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses. No pair wise comparisons showed significant differences in means.

Hypothesis 3E

Hypothesis 3E was retained. Group and degree of high school mathematics preparation did not significantly interact on achievement in comparing centers, spreads, and graphical representations of related data sets. The p-value exceeded 0.05.

Hypothesis 3E.1

Hypothesis 3E.1 was retained. There was no significant difference among the means of basic, average and advanced degree of high school mathematics preparation in achievement in comparing centers, spreads, and graphical representations of related data sets. The p-value exceeded 0.05.

Hypothesis 3F

Hypothesis 3F was retained. Group and degree of high school mathematics preparation did not significantly interact on achievement in using scatter plots and lines of best fit. The p-value exceeded 0.05.

Hypothesis 3F.1

Hypothesis 3F.1 was retained. There was no significant difference among the means of basic, average and advanced degree of high school mathematics preparation in achievement in using scatter plots and lines of best fit. The p-value exceeded 0.05.

Table 4. Summary of Analysis of Variance Comparing Effect of Group Membership and Number of College Math and/or Statistics Classes Taken on Achievement

Source	df	MS	F-ratio	P-value
Overall Achievement (Hyp. 4A)				
Group	3	84.406	5.017	.002
College math/stat classes	4	40.307	2.396	.052
Group*College math/stat classes	12	25.876	1.538	.112
Error	212	16.826		
Sub test 1 Achievement (Hyp. 4B)				
Group	3	23.965	4.634	.004
College math/stat classes	4	5.485	1.061	.377
Group*College math/stat classes	12	9.514	1.840	.044
Error	212	5.172		
Sub test 2 Achievement (Hyp. 4C)				
Group	3	3.065	3.026	.031
College math/stat classes	4	3.150	3.110	.016
Group*College math/stat classes	12	1.336	1.319	.209
Error	212	1.013		
Sub test 3 Achievement (Hyp. 4D)				
Group	3	4.892	5.274	.002
College math/stat classes	4	.920	.992	.413
Group*College math/stat classes	12	.946	1.020	.432
Error	212	.927		
Sub test 4 Achievement (Hyp. 4E)				
Group	3	1.474	1.891	.132
College math/stat classes	4	.733	.941	.441
Group*College math/stat classes	12	.588	.755	.696
Error	212	.779		
Sub test 5 Achievement (Hyp. 4F)				
Group	3	3.933	1.649	.179
College math/stat classes	4	3.947	1.655	.162
Group*College math/stat classes	12	1.989	.834	.615
Error	212	2.385		

Hypothesis 4A

Hypothesis 4A was retained. Group and number of college math and/or statistics classes taken did not significantly interact on overall achievement. The p-value exceeded 0.05.

Hypothesis 4A.1

Hypothesis 4A.1 was retained. There was not a significant difference among the means of different number of college mathematics and/or statistics classes taken in overall achievement. The p-value exceeded 0.05.

Hypothesis 4B

Hypothesis 4B retained. Group and number of college math and/or statistics classes taken did not significantly interact on achievement when finding, describing and interpreting mean, median and mode. The p-value exceeded 0.05.

Hypothesis 4B.1

Hypothesis 4B.1 was retained. There was not a significant difference among the means of different number of college mathematics and/or statistics classes taken achievement when finding, describing and interpreting mean, median and mode. The p-value exceeded 0.05.

Hypothesis 4C

Hypothesis 4C was retained. Group and number of college math and/or statistics classes taken did not significantly interact on achievement in interpreting the spread of a set of data. The p-value exceeded 0.05.

Hypothesis 4C.1

Hypothesis 4C.1 was rejected. There was a significant difference among the means of different number of college mathematics and/or statistics classes taken in achievement in interpreting the spread of a set of data. The mean of students who took no college math and/or statistics classes was 3.15. The mean of students who took one

college math and/or statistics classes was 3.37. The mean of students who took two college math and/or statistics classes was 3.97. The mean of students who took three college math and/or statistics classes was 3.63. The mean of students who took four or more college math and/or statistics classes was 4.20.

A Newman-Keuls post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses. The mean of students who took no college math and/or statistics classes was significantly lower than both the mean of students who took three college math and/or statistics classes and the mean of students who took four or more college math and/or statistics classes. The mean of students who took one college math and/or statistics class was significantly lower than the mean of students who took four or more college math and/or statistics classes.

Hypothesis 4D

Hypothesis 4D was retained. Group and number of college math and/or statistics classes taken did not significantly interact on achievement in understanding the meaning of the shape and features of a graph. The p-value exceeded 0.05.

Hypothesis 4D.1

Hypothesis 4D.1 was retained. There was no significant difference among the means of different number of college mathematics and/or statistics classes taken in achievement in understanding the meaning of the shape and features of a graph. The p-value exceeded 0.05.

Hypothesis 4E

Hypothesis 4E was retained. Group and number of college math and/or statistics classes taken did not significantly interact on achievement in comparing centers, spreads, and graphical representations of related data sets. The p-value exceeded 0.05.

Hypothesis 4E.1

Hypothesis 4E.1 was retained. There was no significant difference among the means of different number of college mathematics and/or statistics classes taken in achievement in comparing centers, spreads, and graphical representations of related data sets. The p-value exceeded 0.05.

Hypothesis 4F

Hypothesis 4F was retained. Group and number of college math and/or statistics classes taken did not significantly interact on achievement in using scatter plots and lines of best fit. The p-value exceeded 0.05.

Hypothesis 4F.1

Hypothesis 4F.1 was retained. There was no significant difference among the means of different number of college mathematics and/or statistics classes taken in achievement in using scatter plots and lines of best fit. The p-value exceeded 0.05.

Table 5. Summary of Analysis of Variance Comparing Effect of Group Membership and Enrollment in Elementary Education Math Option on Achievement

Source	df	MS	F-ratio	P-value
Overall Achievement (Hyp. 5A)				
Group	3	67.627	3.774	.011
Math option	4	23.961	1.337	.257
Group*Math option	4	9.893	.552	.698
Error	220	17.919		
Sub test 1 Achievement (Hyp. 5B)				
Group	3	18.801	3.437	.016
Math option	4	4.266	.780	.539
Group*Math option	4	3.829	.700	.593
Error	220	5.470		
Sub test 2 Achievement (Hyp. 5C)				
Group	3	3.244	2.973	.033
Math option	4	1.080	.990	.414
Group*Math option	4	.594	.544	.703
Error	220	1.091		
Sub test 3 Achievement (Hyp. 5D)				
Group	3	2.705	2.882	.037
Math option	4	.431	.459	.766
Group*Math option	4	.233	.249	.910
Error	220	.938		
Sub test 4 Achievement (Hyp. 5E)				
Group	3	1.950	2.512	.059
Math option	4	.340	.439	.781
Group*Math option	4	1.020	1.314	.266
Error	220	.776		
Sub test 5 Achievement (Hyp. 5F)				
Group	3	2.174	.878	.453
Math option	4	1.931	.781	.539
Group*Math option	4	.590	.239	.916
Error	220	2.474		

Hypothesis 5A

Hypothesis 5A was retained. Group and whether or not the student was in the Elementary Education Program math option did not significantly interact on overall achievement. The p-value exceeded 0.05.

Hypothesis 5A.1

Hypothesis 5A.1 was retained. There was no significant difference among the means students enrolled in the math option, those who are not enrolled in the math option and those who are undecided in overall achievement. The p-value exceeded 0.05.

Hypothesis 5B

Hypothesis 5B was retained. Group and whether or not the student was in the Elementary Education Program math option did not significantly interact on achievement when finding, describing and interpreting mean, median and mode. The p-value exceeded 0.05.

Hypothesis 5B.1

Hypothesis 5B.1 was retained. There was no significant difference among the means students enrolled in the math option, those who are not enrolled in the math option and those who are undecided achievement when finding, describing and interpreting mean, median and mode. The p-value exceeded 0.05.

Hypothesis 5C

Hypothesis 5C was retained. Group and whether or not the student was in the Elementary Education Program math option did not significantly interact on achievement in interpreting the spread of a set of data. The p-value exceeded 0.05.

Hypothesis 5C.1

Hypothesis 5C.1 was retained. There was no significant difference among the means students enrolled in the math option, those who are not enrolled in the math option

and those who are undecided in achievement in interpreting the spread of a set of data. The p-value exceeded 0.05.

Hypothesis 5D

Hypothesis 5D was retained. Group and whether or not the student was in the Elementary Education Program math option did not significantly interact on achievement in understanding the meaning of the shape and features of a graph. The p-value exceeded 0.05.

Hypothesis 5D.1

Hypothesis 5D.1 was retained. There was no significant difference among the means students enrolled in the math option, those who are not enrolled in the math option and those who are undecided in achievement in understanding the meaning of the shape and features of a graph. The p-value exceeded 0.05.

Hypothesis 5E

Hypothesis 5E was retained. Group and whether or not the student was in the Elementary Education Program math option did not significantly interact on achievement in comparing centers, spreads, and graphical representations of related data sets. The p-value exceeded 0.05.

Hypothesis 5E.1

Hypothesis 5E.1 was retained. There was no significant difference among the means students enrolled in the math option, those who are not enrolled in the math option and those who are undecided in achievement in comparing centers, spreads, and graphical representations of related data sets. The p-value exceeded 0.05.

Hypothesis 5F

Hypothesis 5F was retained. Group and whether or not the student was in the Elementary Education Program math option did not significantly interact on achievement in using scatter plots and lines of best fit. The p-value exceeded 0.05.

Hypothesis 5F.1

Hypothesis 5F.1 was retained. There was no significant difference among the means of students enrolled in the math option, those who are not enrolled in the math option and those who are undecided in achievement in using scatter plots and lines of best fit. The p-value exceeded 0.05.

Table 6. Summary of Analysis of Variance Comparing Effect of grade taught while student teaching and whether or not they taught math while student teaching on Achievement

Source	df	MS	F-ratio	P-value
Overall Achievement (Hyp. 6A)				
Grade taught	2	5.590	.241	.787
Taught math	1	.273	.012	.914
Grade taught*Taught math	1	34.177	1.476	.231
Error	44	23.157		
Sub test 1 Achievement (Hyp. 6B)				
Grade taught	2	1.089	.142	.868
Taught math	1	2.663	.348	.558
Grade taught*Taught math	1	3.554	.464	.499
Error	44	7.654		
Sub test 2 Achievement (Hyp. 6C)				
Grade taught	2	.237	.187	.830
Taught math	1	.0012	.010	.922
Grade taught*Taught math	1	1.265	.999	.323
Error	44	1.267		
Sub test 3 Achievement (Hyp. 6D)				
Grade taught	2	.962	1.282	.288
Taught math	1	7.084	9.446	.004
Grade taught*Taught math	1	.145	.193	.663
Error	44	.750		
Sub test 4 Achievement (Hyp. 6E)				
Grade taught	2	1.431	1.975	.151
Taught math	1	.508	.701	.407
Grade taught*Taught math	1	.508	.701	.407
Error	44	.725		
Sub test 5 Achievement (Hyp. 6F)				
Grade taught	2	1.586	.449	.641
Taught math	1	.486	.138	.712
Grade taught*Taught math	1	7.426	2.104	.154
Error	44	3.529		

Hypothesis 6A

Hypothesis 6A was retained. Grade taught while student teaching and whether or not the student teacher taught math did not significantly interact on overall achievement.

The p-value exceeded 0.05.

Hypothesis 6A.1

Hypothesis 6A.1 was retained. There was no significant difference among the means of student teachers in grades PreK-2, 3-5 and 6-8 in overall achievement. The mean of student teachers in grades PreK-2 was 21.06, the mean of student teachers in grades 3-5 was 22.46, and the mean of student teachers in grades 6-8 was 19.88. The p-value exceeded 0.05.

Hypothesis 6A.2

Hypothesis 6A.2 was retained. There was no significant difference between the means of those who taught math while student teaching and those who did not teach math while student teaching in overall achievement. The mean of those who taught math while student teaching was 21.83 and the mean of those who did not teach math while student teaching was 19.86. The p-value exceeded 0.05.

Hypothesis 6B

Hypothesis 6B was retained. Grade taught while student teaching and whether or not the student teacher taught math did not significantly interact on achievement when finding, describing and interpreting mean, median and mode. The p-value exceeded 0.05.

Hypothesis 6B.1

Hypothesis 6B.1 was retained. There was no significant difference among the means of student teachers in grades PreK-2, 3-5 and 6-8 in achievement when finding, describing and interpreting mean, median and mode. The mean of student teachers in grades PreK-2 was 5.82, the mean of student teachers in grades 3-5 was 6.25, and the mean of student teachers in grades 6-8 was 5.88. The p-value exceeded 0.05.

Hypothesis 6B.2

Hypothesis 6B.2 was retained. There was no significant difference between the means of those who taught math while student teaching and those who did not teach math while student teaching in achievement when finding, describing and interpreting mean, median and mode. The mean of those who taught math while student teaching was 6.02 and the mean of those who did not teach math while student teaching was 6.14. The p-value exceeded 0.05.

Hypothesis 6C

Hypothesis 6C was retained. Grade taught while student teaching and whether or not the student teacher taught math did not significantly interact on achievement in interpreting the spread of a set of data. The p-value exceeded 0.05.

Hypothesis 6C.1

Hypothesis 6C.1 was retained. There was no significant difference among the means of student teachers in grades PreK-2, 3-5 and 6-8 in achievement in interpreting the spread of a set of data. The mean of student teachers in grades PreK-2 was 3.24, the mean of student teachers in grades 3-5 was 3.54, and the mean of student teachers in grades 6-8 was 3.00. The p-value exceeded 0.05.

Hypothesis 6C.2

Hypothesis 6C.2 was retained. There was no significant difference between the means of those who taught math while student teaching and those who did not teach math while student teaching in interpreting the spread of a set of data. . The mean of those

who taught math while student teaching was 3.40 and the mean of those who did not teach math while student teaching was 3.00. The p-value exceeded 0.05.

Hypothesis 6D

Hypothesis 6D was retained. Grade taught while student teaching and whether or not the student teacher taught math did not significantly interact on achievement in understanding the meaning of the shape and features of a graph. The p-value exceeded 0.05.

Hypothesis 6D.1

Hypothesis 6D.1 was retained. There was no significant difference among the means of student teachers in grades PreK-2, 3-5 and 6-8 in achievement in understanding the meaning of the shape and features of a graph. The mean of student teachers in grades PreK-2 was 4.88, the mean of student teachers in grades 3-5 was 4.75, and the mean of student teachers in grades 6-8 was 4.38. The p-value exceeded 0.05.

Hypothesis 6D.2

Hypothesis 6D.2 was rejected. There was a significant difference between the means of those who taught math while student teaching and those who did not teach math while student teaching in achievement in understanding the meaning of the shape and features of a graph. The mean of those who taught math while student teaching was 4.88 and the mean of those who did not teach math while student teaching was 3.86. The p-value less than 0.05.

A Newman-Keuls post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses. The mean of students who taught math while student

teaching was significantly higher than the means of students who did not teach math while student teaching.

Hypothesis 6E

Hypothesis 6E was retained. Grade taught while student teaching and whether or not the student teacher taught math did not significantly interact on achievement in comparing centers, spreads, and graphical representations of related data sets. The p-value exceeded 0.05.

Hypothesis 6E.1

Hypothesis 6E.1 was retained. There was no significant difference among the means of student teachers in grades PreK-2, 3-5 and 6-8 in achievement in comparing centers, spreads, and graphical representations of related data sets. The mean of student teachers in grades PreK-2 was 3.12, the mean of student teachers in grades 3-5 was 3.29, and the mean of student teachers in grades 6-8 was 2.50. The p-value exceeded 0.05.

Hypothesis 6E.2

Hypothesis 6E.2 was retained. There was no significant difference between the means of those who taught math while student teaching and those who did not teach math while student teaching in achievement in comparing centers, spreads and graphical representations of related data sets. The mean of those who taught math while student teaching was 3.17 and the mean of those who did not teach math while student teaching was 2.71. The p-value exceeded 0.05.

Hypothesis 6F

Hypothesis 6F was retained. Grade taught while student teaching and whether or not the student teacher taught math did not significantly interact on achievement in using scatter plots and lines of best fit. The p-value exceeded 0.05

Hypothesis 6F.1

Hypothesis 6F.1 was retained. There was no significant difference among the means of student teachers in grades PreK-2, 3-5 and 6-8 in achievement in using scatter plots and lines of best fit. The mean of student teachers in grades PreK-2 was 6.88, the mean of student teachers in grades 3-5 was 7.71, and the mean of student teachers in grades 6-8 was 6.50. The p-value exceeded 0.05.

Hypothesis 6F.2

Hypothesis 6F.2 was retained. There was no significant difference between the means of those who taught math while student teaching and those who did not teach math while student teaching in achievement in using scatter plots and lines of best fit. The mean of those who taught math while student teaching was 7.33 and the mean of those who did not teach math while student teaching was 6.57. The p-value exceeded 0.05.

Multiple Regression Analyses

Hypothesis 7A

Table 7. Model Summary for Total Score

Model	R	R ²	Adjusted R ²	Std. Error of the Estimate
1	.350 ^a	.123	.009	4.5179

- a. Predictors: (constant), math option, age when enrolled in MATH 130, # college math/stat classes taken, gender, level of HS preparation, group-class

Table 8. ANOVA for Total Score

Model	Sum of Squares	df	Mean Square	F	p-value
Regression	642.504	6	107.084	5.246	.000
Residual	4592.513	225	20.411		
Total	5235.017	231			

Hypothesis 7A was rejected. The set of independent variables (gender, age when enrolled in MATH 130, number of high school math classes taken and passed, number of college math and or statistics classes taken and passed, whether or not the student was enrolled in Elementary Education program math option) did explain a significant proportion of the variability in overall achievement. The set of independent variables explain 12.3 % of the variability in total score among the elementary education majors. The p-value was less than 0.05.

Hypothesis 7B

Table 9. Model Summary for achievement when finding, describing and interpreting mean, median and mode

Model	R	R ²	Adjusted R ²	Std. Error Estimate
1	.280 ^a	.079	.054	2.4864

a. Predictors: (constant), math option, age when enrolled in MATH 130, # college math/stat classes taken, gender, level of HS preparation, group-class

Table 10. ANOVA for achievement when finding, describing and interpreting mean, median and mode

Model	Sum of Squares	df	Mean Square	F	p-value
Regression	118.749	6	19.792	3.201	.005
Residual	1391.027	225	6.182		
Total	1509.779	231			

Hypothesis 7B was rejected. The set of independent variables (gender, age when enrolled in MATH 130, number of high school math classes taken and passed, number of college math and or statistics classes taken and passed, and whether or not the student was enrolled in Elementary Education program math option) did explain a significant proportion of the variability in achievement when finding, describing and interpreting mean, median and mode. The set of independent variables explain 7.9 % of the variability in achievement when finding, describing and interpreting mean, median and mode among the elementary education majors. The p-value was less than 0.05.

Hypothesis 7C

Table 11. Model Summary for achievement in interpreting the spread of a set of data

Model	R	R ²	Adjusted R ²	Std. Error Estimate
1	.372 ^a	.138	.115	1.1098

a. Predictors: (constant), math option, age when enrolled in MATH 130, # college math/stat classes taken, gender, level of HS preparation, group-class

Table 12. ANOVA for achievement in interpreting the spread of a set of data

Model	Sum of Squares	df	Mean Square	F	p-value
Regression	44.409	6	7.401	6.010	.000
Residual	277.108	225	1.232		
Total	321.517	231			

Hypothesis 7C was rejected. The set of independent variables (gender, age when enrolled in MATH 130, number of high school math classes taken and passed, number of college math and or statistics classes taken and passed, and whether or not the student was enrolled in Elementary Education program math option) did explain a significant proportion of the variability in achievement in interpreting the spread of a set of data. The set of independent variables explain 7.9 % of the variability in achievement in interpreting the spread of a set of data among the elementary education majors. The p-value was less than 0.05.

Hypothesis 7D

Table 13. Model Summary for achievement in understanding the meaning of the shape and features of a graph

Model	R	R ²	Adjusted R ²	Std. Error of the Estimate
1	.225 ^a	.051	.051	1.0026

- a. Predictors: (constant), math option, age when enrolled in MATH 130, # college math/stat classes taken, gender, level of HS preparation, group-class

Table 14. ANOVA for achievement in understanding the meaning of the shape and features of a graph

Model	Sum of Squares	df	Mean Square	F	p-value
Regression	12.078	6	2.013	2.002	.066
Residual	226.194	225	1.005		
Total	238.272	231			

Hypothesis 7D was retained. The set of independent variables (gender, age when enrolled in MATH 130, number of high school math classes taken and passed, number of college math and or statistics classes taken and passed, and whether or not the student was enrolled in Elementary Education program math option) did not explain a significant proportion of the variability in achievement in understanding the meaning of the shape and features of a graph. The p-value was greater than 0.05.

Hypothesis 7E

Table 15. Model Summary for achievement in comparing centers, spreads, and graphical representations of related data sets

Model	R	R ²	Adjusted R ²	Std. Error of the Estimate
1	.253 ^a	.064	.039	.8772

- a. Predictors: (constant), math option, age when enrolled in MATH 130, # college math/stat classes taken, gender, level of HS preparation, group-class.

Table 16. ANOVA for achievement in comparing centers, spreads, and graphical representations of related data sets

Model	Sum of Squares	df	Mean Square	F	p-value
Regression	11.869	6	1.978	2.571	.020
Residual	173.127	225	.769		
Total	184.996	231			

Hypothesis 7E was rejected. The set of independent variables (gender, age when enrolled in MATH 130, number of high school math classes taken and passed, number of college math and or statistics classes taken and passed, and whether or not the student was enrolled in Elementary Education program math option) did explain a significant proportion of the variability in achievement in comparing centers, spreads, and graphical representations of related data sets. The set of independent variables explain 6.4 % of the

variability in achievement in comparing centers, spreads, and graphical representations of related data sets among the elementary education majors. The p-value was less than 0.05.

Hypothesis 7F

Table 17. Model Summary for achievement in using scatter plots and lines of best fit

Model	R	R ²	Adjusted R ²	Std. Error of the Estimate
1	.260 ^a	.068	.043	1.5671

a. Predictors: (constant), math option, age when enrolled in MATH 130, # college math/stat classes taken, gender, level of HS preparation, group-class

Table 18. ANOVA for achievement in using scatter plots and lines of best fit

Model	Sum of Squares	df	Mean Square	F	p-value
Regression	40.069	6	6.678	2.719	.014
Residual	552.551	225	2.456		
Total	592.621	231			

Hypothesis 7F was rejected. The set of independent variables (gender, age when enrolled in MATH 130, number of high school math classes taken and passed, number of college math and or statistics classes taken and passed, and whether or not the student was enrolled in Elementary Education program math option) did explain a significant proportion of the variability in achievement in using scatter plots and lines of best fit. The set of independent variables explain 6.8 % of the variability in achievement in using scatter plots and lines of best fit among the elementary education majors. The p-value was less than 0.05.

Descriptive Statistics for Short Answer Questions

All short answer (interpretive) questions were scored with a specific rubric that followed the same basic pattern:

1. no answer
2. wrong answer
3. right answer, no explanation
4. right answer, partial /unclear explanation
5. right answer, complete/clear explanation

The researcher calculated the total points each student received on the short answer (interpretive) questions and then used a one-way ANOVA to determine if there were significant differences among the means of the four groups. There was a significant difference among the means of the four groups in total short answer achievement. The means for the four groups were 22.60 (MATH 130), 25.29 (MATH 131), 26.57 (EDEL 333) and 24.08 (EDEL 410). The p-value was less than 0.05.

Table 19. ANOVA for total score on interpretive questions

	Sum of Squares	df	Mean Square	F	p-value
Between Groups	578.337	3	192.779	11.423	.000
Within Groups	3847.939	228	16.877		
Total	4426.276	231			

A Newman-Keuls post hoc multi comparison statistic was utilized to test all possible pair wise hypotheses. The mean of students in MATH 130 was significantly less than students who were in MATH 131 and EDCI 333. The mean of students in EDCI 410 was significantly less than students in EDCI 333 and the mean of students in MATH 131 was significantly less than the mean of students in EDCI 333.

Summary

This research used one- and two-way analyses of variance and multiple regressions to test eighty-nine individual hypotheses. Seventeen of the hypotheses were rejected while seventy-two were retained.

CHAPTER 5

SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

Summary of the Study

This study was designed to investigate whether elementary education majors in the Montana State University Teacher Education Program acquire and retain knowledge of statistical data analysis concepts and skills consistent with expectations specified in NCTM *Principles and Standards: A Discussion Draft* (1998). In particular, this study focused on student knowledge, mastery and retention of the following topics in statistical data analysis: Finding, describing and interpreting mean, median and mode; interpreting the spread of a set of data; understanding the meaning of the shape and features of a graph; comparing centers, spreads, and graphical representations of related data sets; and using scatter plots and lines of best fit. Relatively new areas of emphasis in elementary education, these topics are discussed at length in the data analysis strand of Standard Five of the National Council of Teachers of Mathematics' *Principles and Standards: A Discussion Draft* (1998).

In order to sample student knowledge relative to statistical data analysis, a pool of items was developed reflecting the content of this strand. Specific items were then chosen from the pool and used in the construction of a research instrument which was a written exam consisting of both demographic (4) and content (34) questions. Experts in

mathematics education and statistics reviewed the individual items and overall construction of the instrument to determine its validity. Subsequently, additions and revisions were made to the instrument in order to achieve a suitable overall composition and format. A rubric was developed for scoring open-response, short answer items. During the Summer Semester of 1999, a pilot study was conducted in order to determine the reliability of the instrument. Final revisions were then made to improve the instrument's overall reliability.

Data collection took place during Fall Semester of 1999 in MATH 130 - Mathematics for Elementary Teachers I, MATH 131 - Mathematics for Elementary Teachers II, EDEL 333 - Teaching Mathematics, and EDEL 410 - Student Teaching. The participants in the study were elementary education majors currently enrolled in those classes. At Montana State University, students in MATH 130 - Mathematics for Elementary Teachers I and MATH 131 - Mathematics for Elementary Teachers II were predominantly freshmen in their first two semesters of college. Content for MATH 130 is primarily the real number system and algebraic concepts while MATH 131 focuses on geometry, statistics, and probability. Students in EDEL 333 - Teaching Mathematics were juniors or seniors who student taught within the next two semesters. The student teachers had just completed their final semester in the Elementary Education Program. The data obtained were then analyzed using the SPSS statistical analysis program at Montana State University and the findings were used to answer the study's research questions.

Conclusions

This study sought to answer the question "To what degree do students enrolled in the Elementary Education Program at Montana State University - Bozeman acquire and retain the statistical data analysis content required for elementary and middle school as defined by the National Council of Teachers of Mathematics?" Data obtained were used to characterize the statistical data analysis knowledge of pre-service elementary education majors relative to both group membership and specific demographic factors. While the following analyses and conclusions discuss the answers to this question in detail, the overall conclusion is clear: Whatever gains are achieved in MATH 131 - Mathematics for Elementary Teachers II are lost by the end of EDEL 410 - Student Teaching. Consequently, students graduating from the Montana State University elementary education program do not possess the statistical data analysis knowledge required to meet current professional standards.

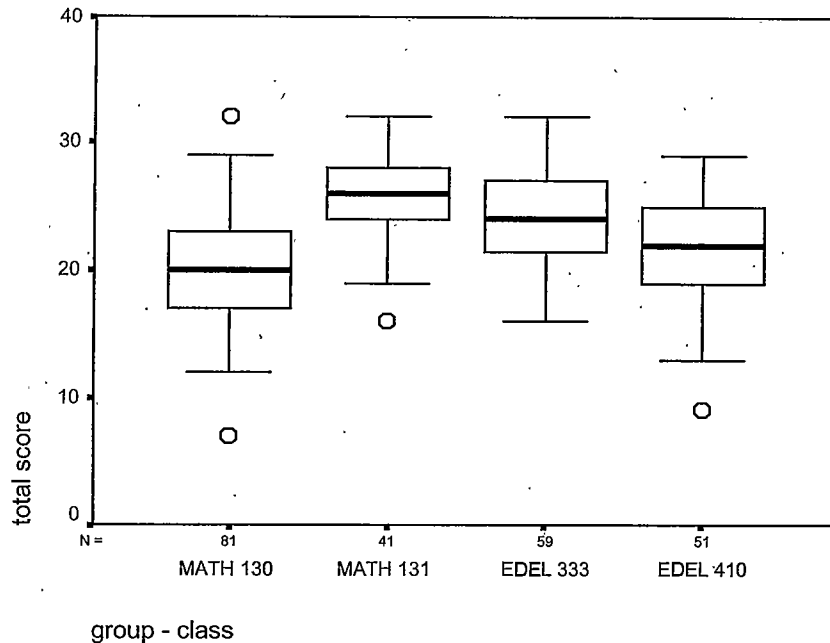
This conclusion is troubling, given the many research findings and the recommendations of important professional organizations that stress the importance of a strong content knowledge base for classroom teachers. Prospective graduates of the Montana State University Elementary Education Program do not have the knowledge that the *Standards* recommend relative to statistical data analysis. In addition, participants are not uniformly capable in their abilities; there is approximately as much variability among all four groups. There was a significant difference among the achievement means of the

four classes. For example, Hypothesis 1A.2 showed a significant difference among the means of the four groups in *overall* achievement with respect to statistical data analysis. The mean overall achievement of students in MATH 130 (19.91) was gathered to be used as baseline data, indicating the statistical data analysis knowledge that students had at the beginning of the elementary education program. A significant increase was observed in the mean of the students who had completed MATH 131(25.52). The mean achievement score of students completing EDEL 333 (24.11) fell slightly, but not enough to be statistically significant. However, an upsetting finding of this study was that the mean achievement score of students who completed EDEL 410 (21.65) was significantly lower than of the two preceding classes. As can be seen in the five-point summaries in Table 20 and the box-and-whisker plots in Figure 8, almost seventy-five percent of the students in EDEL 410 scored lower than the upper fifty percent of students in MATH 131 and lower than almost fifty percent of the students in EDEL 333.

Table 20. Five point summaries for Total Achievement excluding outliers

	Minimum	First quartile	Median	Third quartile	Maximum
MATH 130	12	17	20	23	29
MATH 131	19	24	26	28	32
EDEL 333	16	21	24	27	32
EDEL 410	13	19	22	25	29

Figure 8. Box-and-Whisker Plots of Total Achievement

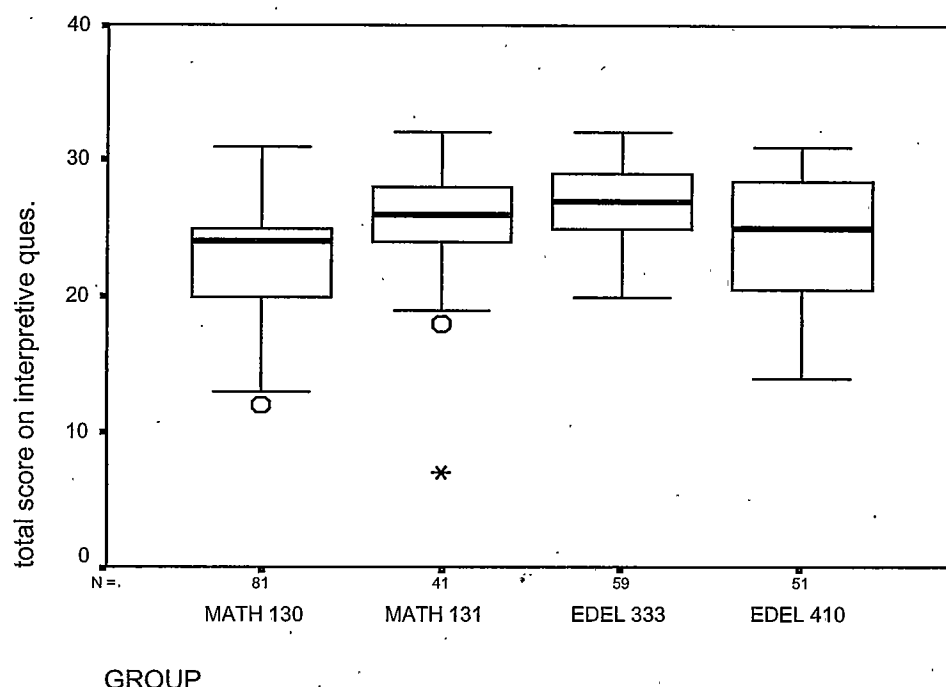


Similar results were obtained when analyzing the total score on the short answer questions (See Table 21 and Figure 9). The bottom fifty percent of students in EDEL 410 scored below almost seventy five percent of the students in EDEL 333. The range of the first and second quartiles was nearly as great as that of the first and second quartiles of MATH 130.

Table 21. Five point summaries for Total score on short answer (interpretive) questions excluding outliers

	Minimum	First quartile	Median	Third quartile	Maximum
MATH 130	13	20	24	25	31
MATH 131	19	23.5	26	28	32
EDEL 333	20	25	27	29	32
EDEL 410	14	20	25	29	31

Figure 9. Total score on short answer (interpretive) questions



For many students, the contexts of statistical questions had little or no bearing on their responses. For instance, in considering question 34 (Figure 10), an EDEL 410 student answered by saying, "no, the average is \$4,650." Ignoring the context of the question, she divided the total of the salary column (\$279,000) by the total of the number of employees column (60). Obviously this student has only the most rudimentary understanding of average and also took no time to evaluate the appropriateness of her answer in relation to the salaries given. Compare the answer given by a student in MATH 131, "This is not a fair representation. Median and mode are both in the \$29500 salary zone - the mean is higher. The best way to get an average with this data is mode." It is troubling to realize that students at the beginning of their careers as students are more able to deal with data and its analysis than those who are about to embark on their careers as teachers.

Figure 10: Question 34 - Short Answer Question

34. The personnel director of a company is recruiting employees. In the interview, he tells a candidate that the average salary of the employees is \$32,400. If the company's salaries are as follows, is his claim a fair representation? Explain.

Salary	No. of Employees
\$80,000	1
\$65,000	1
\$49,000	3
\$35,000	16
\$29,500	34
\$20,500	6

The hypotheses that assessed group means also showed that there was a significant difference among the means of the four groups in finding, describing and interpreting mean, median and mode; interpreting the spread of a set of data; understanding the meaning of the shape and features of a graph; and using scatter plots and lines of best fit. In each case, the mean of EDEL 410 was significantly less than both EDEL 333 and MATH 131. The percentage of students with incorrect responses in all groups is disturbing given that these people will be teaching this topic to elementary and middle school students in the next one to three years.

While the lack of retention of statistical data analysis knowledge is distressing, it is consistent with the findings of Ball (1990), Zazkis & Campbell (1994), Putt (1995), Rusch (1997), and Desmond (1997) who found that pre-service teachers' mathematical knowledge was weak and rule driven. The teaching profession also recognizes the complexity of preparing teachers. NCTM (1991) and Loucks-Horsley (1997) emphasize that teacher preparation and professional development must be viewed as ongoing processes and that fundamental change happens over time. It may even be that we can

never prepare elementary teachers well enough before they enter the classroom. "In fact, it appears that the new mathematical understanding teachers must develop and the teaching situation they must negotiate are too varied, complex, and content-dependent to be anticipated in one or even several courses. Thus, teachers must become learners in their own classrooms (Russell, 1997 p 253)."

Discussion of Independent Variables

Age and Gender

Because mathematics education occurs in a social context in which gender has been a recurring theme, and because enrollment in the Elementary Education Program is predominately female, it seemed logical to investigate whether gender was related to the main research questions posed in this study. In addition, since students over traditional age (25) now constitute a significant portion of the population of preservice teachers, age was also investigated as a factor. Neither age nor gender was determined to be statistically significant when trying to explain variability in total achievement or achievement in any of the five subtests. These results are consistent with results found by Roberts (1995) and White (1986) who found no significant differences in achievement in geometry (Roberts) or essential elements of elementary school mathematics (White).

Math Option of the Elementary Education Program

At Montana State University elementary education majors who choose to enroll in the math option, take eighteen additional credits in Mathematics and Statistics in place of

the electives that elementary education majors are required to take. While the number of students enrolled in the Math Option of the Elementary Education Program was small ($n=17$), there were enough students to determine if there was a significant difference among the means of those who were enrolled in the option and those who were not. It was troubling to find that there was no significant difference in achievement between the students who were enrolled in the math option and those who were not. Students enrolled in the Math option were members of all four classes. One student was in MATH 130, six in MATH 131, eight in EDEL 333, and two in EDEL 410. Since it is reasonable to assume that the students who were enrolled in both MATH 130 and MATH 131 might not have had the opportunity in their college program to take all the classes that are required of the math option, the researcher removed the seven students in those classes and performed a correlation analysis to determine if there was a significant relationship between enrollment in the math option (only the juniors and seniors) and total score. There was no relationship ($p>0.05$).

Further examination of the data caused the researcher to doubt the validity of the demographic responses. Of the ten junior and senior students who indicated they were enrolled in the math option, two indicated that they had only taken one college math and/or statistics class (other than MATH 085, MATH 103, MATH 105, MATH 130, and MATH 131), two indicated taking two additional classes, two indicated taking three additional classes and four indicated taking four or more additional classes. Given the nature of the Blocks and the scheduling that occurs because of them, it is almost impossible for a student to already be enrolled in the Blocks, be enrolled in the math

option and only have taken one or two additional classes since six additional classes are required. An additional concern, 'STATS 216 - Elementary Statistics, was a required course for all students enrolled in the Math Option, however this research did not collect information on specific college classes taken by students enrolled in the Math Option. Therefore caution should be taken when interpreting the meaning of the statistical findings that test the independent variable of whether or not the students were actually enrolled in the math option.

It should be noted, however, it is a common practice among elementary education majors who have chosen the math option to take one or more math classes after they have student taught. Since this data was gathered during fall semester, it is possible that math option enrollees in EDEL 410 - Student Teaching could be in this situation. It is beyond the scope of this study to track this information.

Level of High School Preparation

Number of College Mathematics and/or Statistics Classes Taken

Multiple regression analysis revealed that the set of independent variables (gender, age when enrolled in MATH 130, number of high school math classes taken and passed, number of college math and or statistics classes taken and passed, and whether or not the student is enrolled in Elementary Education program math option) did explain a significant proportion of the variability in the following: total achievement; achievement in finding describing and interpreting mean, median and mode; achievement in interpreting the spread of the data; achievement in understanding centers, spreads, and graphical representation of the data; and achievement in using scatter plots and lines of

best fit. However, even though the findings are statistically significant they are of little practical significance. The highest R^2 found was for Subtest 2 - interpreting the spread of the data. Even then, knowledge of the independent variables only explained 13.8 percent of the variability in achievement. In order of importance, those independent variables that did explain a significant proportion of the variability were high school preparation, number of college math and or statistics classes taken and group membership. Those independent variables that did not explain a significant proportion of the variability were age, gender, and whether or not the student was enrolled in the Math Option of the Elementary Education Program.

While the data from this study are of little practical significance they are in line with results found by White (1986), Dyas (1993), and Roberts (1995). All three studies found that high school preparation of preservice teachers had a significant positive relationship to achievement in college mathematics content and/or methods courses. In addition, Dyas also found that there was a significant positive relationship between college math classes taken and achievement in college mathematics content and/or methods courses.

Implications for Teacher Education

In light of the findings presented in this study, the following recommendations are offered regarding the Montana State University Elementary Education Program:

1. Change when the two mathematics content courses are required to be taken in the program sequence. Typically the students in MATH 130 and MATH 131 are freshmen that may not yet have clearly defined their needs as prospective teachers. Perhaps

moving the mathematics content courses to the sophomore year would allow the students one more year of thought and maturity in the choice of their career. This would be consistent but possibly less helpful than Friel and Bright's (1997) suggestion that having a mathematics content course in the spring of the junior year, followed by methods in fall of the senior year (to address pedagogy and children's thinking) was a viable option in preservice education. Cornell (1999) observed that several of his university students were reluctant to delve into questions of why a particular strategy, formula or algorithm worked. Instead they wanted to be given a formula they could memorize. Grossnickle, Perry, and Reckzeh (1990) noted that the importance of developing a student's ability to relate math to real-life requirements, which in turn, give meaning to mathematical operations, as well as enhancing learning and a positive attitude. Therefore, it seems reasonable that relating their content classes to their future career would be a 'real-life requirement'!

In actuality, changing the scheduling of just the mathematics content classes within the elementary education program would have program wide ramifications. All content fields could suffer the same fate if their classes were moved to the freshmen year.

2. Have the content and methods integrated within all three courses (MATH 130, MATH 131, and EDEL 333) that are required. Courses on subject-matter topics have been disconnected from courses on teaching methods. Students are not making the connections. Darling-Hammond (1999) found that "shoehorning unintegrated courses into the four-year undergraduate program created unhappy trade-offs between deep learning in a disciplinary field and serious understand of teaching and learning" (p.30). A

possible solution would be to have three courses that are all an integrated content/methods format versus two that are content driven and one that is methods driven. This would be a drastic move from the current format of teaching content as a totally isolated experience. However, this would be in line with results found by Jones (1995), Benbow (1993) and Floden (1990) who favorably reported on this arrangement. Past changes suggested by Hutchison (1992) have included integrating content and pedagogical knowledge within courses for elementary education majors. Harpole (1997) reported on the success of a three-semester sequence of integrated content/methods classes developed for preservice elementary education teachers at Mississippi State University. The three courses at Mississippi State University focused on current science education research, methods of teaching by guided discovery, and newly developed curriculum materials. Heikkinen and McDevitt (1997) also reported success with integration of all preservice components - content courses, methods of teaching courses, education courses, and early, sustained field experiences - in the elementary education program.

3. Require all elementary education majors to take more specialized mathematics courses than the required two in existence now. Classes should feature strong mathematics components including course work in geometry, algebra, probability and statistics, basic components of calculus and mathematical modeling (NCTM, 1991, Leitzel, 1991). All concepts should be taught from a conceptual viewpoint rather than from a traditional theoretical point of view (NCTM, 1991). The statistics courses should be taught using hands-on activities for producing data and illustrating concepts, and using

simulation as a device for understanding probability and the basic ideas of inference. Students should see statistics as an organized way to solve problems. The University of Northern Iowa (Ward, 1997) made an extensive revision of their elementary education program in response to the NCTM Standards. Their project, which involved both math and science, began in 1988 and by 1997 they had developed six new math courses and extensively revised three existing math courses.

4. Strengthen the communication with Montana Office of Public Instruction and the Montana Council of Teachers of Mathematics to work with secondary school counselors to advise prospective teachers of the importance of a strong high school mathematics preparation. Recommend to the high school counselors that prospective elementary teachers have at least three years of mathematics concluding with a minimum of pre-Calculus.

In addition, Montana State University should make continuing statistical education workshops and courses available to all interested elementary teachers. According to Schaeffer (2000), of all the mathematical topics now appearing in elementary curricula, statistics is the newest and ranks at the top in terms of the lack of preparation teachers have to teach this subject matter. Given the lack of knowledge that the current elementary education majors possess when the topic is actively taught within the curriculum, it seems to be obvious that practicing teachers who did not have statistics in their university work are also in need of workshops to increase their knowledge base.

Recommendations for Future Research

The findings of this study suggest several areas for further research.

Questions arise as to the extent that elementary education majors acquire and retain knowledge in other areas of statistics not addressed in this study. This model provided a foundation for further study and suggests that it is necessary. It is suggested that this study be replicated to determine if there is retention of knowledge in those areas.

It is further suggested that this study be replicated to study the acquisition and retention of knowledge in other areas of elementary mathematics such as Algebra, Geometry, and Measurement.

Since the National Council for Social Studies (1994), the Geography Education Standards Project (1994), and The National Council of Teachers of English, together with the International Reading Association (1996) have documented the need for statistical skills within their respective disciplines, an evaluation of the content taught in other methods courses should be done to see if the statistics that is recommended by the specific disciplines is being taught at Montana State University.

It is recommended that the study be replicated and extended to include practicing teachers. Does the apparent decay of knowledge continue, or do practicing teachers in turn gain understanding through their teaching?

Additional Consideration for Future Research - Instrumentation

Even though a pilot study was conducted, after using the instrument and analyzing results it became evident that the current configuration of question 3 wasn't directive enough. Before utilizing this test instrument it is recommended that question 3 in the test instrument which asked students to indicate the number of college math and statistics classes taken and passed (other than MATH 085, MATH 103, MATH 105, MATH 130, and MATH 131) should be changed to reflect the style of question 2 which asked for specific classes taken in high school. As it is, question 3 did not allow the researcher to determine the nature or level of college mathematics and statistics courses taken.

Answers to question 40, which asked if students in EDEL 410 - Student Teaching had taught math during their student teaching experiences, did not yield results which were helpful in explaining variability during analysis. This researcher suggests more informative results could be found if question 40 were rewritten to ask specifically if EDEL 410 student taught statistical data analysis during their student teaching experience.

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APPENDICES

Appendix A
Testing Instrument

Name _____ Student ID number _____ Gender _____

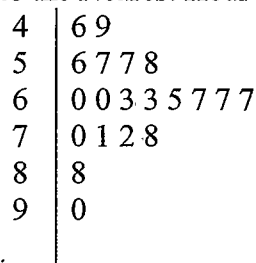
Answer questions 1-31 by blackening the correct answer on the accompanying bubble sheet.

1. Age when enrolled in MATH 130
a) 25 or younger b) 26 or older
2. Check all the math classes that you took in high school

☐ Basic Math	☐ Geometry I	☐ Integrated Math I
☐ General Math	☐ Discrete Math	☐ Integrated Math II
☐ Business Math	☐ Trigonometry	☐ Integrated Math III
☐ Pre Algebra	☐ Pre-Calculus	☐ Integrated Math IV
☐ Algebra I	☐ Calculus	☐ Other: (Specify)
☐ Algebra II	☐ Statistics	
3. Number of college math and statistics classes taken and passed (other than MATH 085, MATH 103, MATH 105, MATH 130, and MATH 131)
a) 0 b) 1 c) 2 d) 3 e) 4 or more
4. Are you enrolled in the Elementary Education Math Option, now?
a) undecided b) yes c) no

Julie tested 20 size AA batteries to see how long each would last. She created this graph.

Lifetime of Batteries
to the Nearest Hour



4 | 9 represents
49 hours

5. The range of the data is
a) 4 - 9 b) 46 - 90 c) 0 - 69 d) 56
6. The mode of the complete set of data is
a) 67 b) 46 c) 90 d) 57, 63

7. The median is
 a) 65 b) 64 c) 63.5 d) 65.5

Choose the set(s) of numbers that fits the descriptions given in each of the following:

- | | | |
|--------------------------------------|--|--|
| 8. The mean is 6.
The range is 6. | 9. The mean is 11.
The median is 11.
The mode is 11. | 10. The mean is 3
The median is 3.
It has no mode. |
|--------------------------------------|--|--|

Set A: 3, 5, 7, 9

Set B: 2, 4, 6, 8

Set C: 2, 3, 4, 15

Set A: 9, 10, 10, 11, 12, 12, 13

Set B: 10, 11, 11, 11, 11, 11, 13

Set C: 9, 11, 11, 11, 11, 12, 12

Set A: 0, 2 $\frac{1}{2}$, 6 $\frac{1}{2}$

Set B: 3, 3, 3, 3

Set C: 1, 2, 4, 5

Use the following information to answer questions 11 and 12.

Sam Slugger's contract with the Columbus Mudcats baseball team says his annual salary will be based on his batting averages for the preceding five seasons. Sam's batting averages for the past five seasons were .145, .130, .160, .130, and .495.

11. If you were Sam, which of the following statistics would you want to use to compute your salary?

a) mean b) median c) mode

12. If you were the general manager of the Mudcats, which statistic would you want to use?

a) mean b) median c) mode

13. Given the following data, calculate the mean, median, and mode

1, 3, 6, 6, 7, 8, 13, 13, 13, 20, 20

a) mean 10

median 13

mode 9

b) mean 11

median 9

mode 13

c) mean 10

median 8

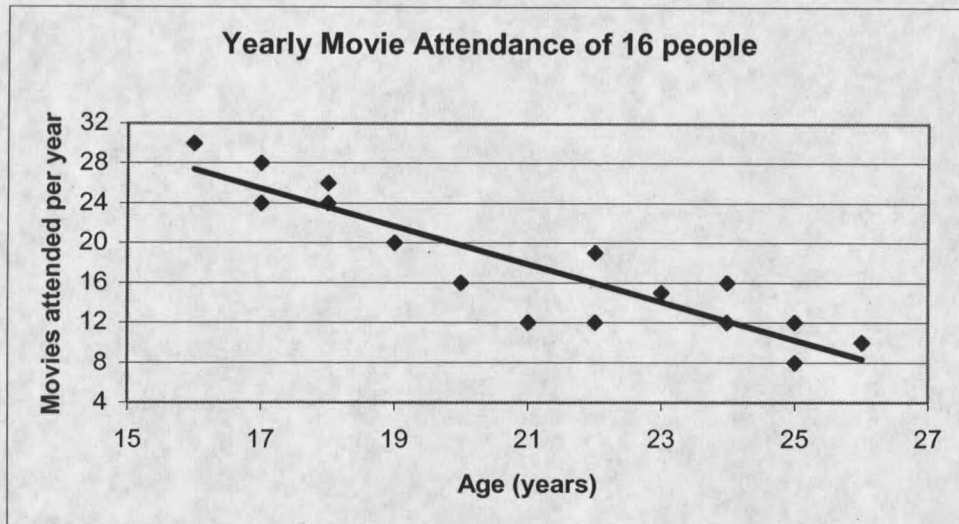
mode 13

d) mean 10

median 9

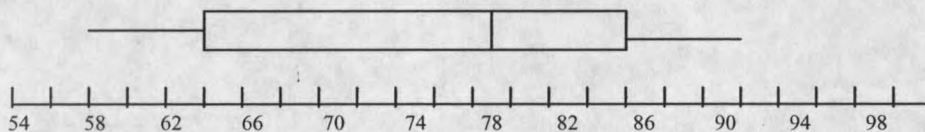
mode 20

Use the following graphical representation to answer the questions 14 and 15.



14. Based on the line of regression, about how many movies does an average 21-yr. old attend?
 a) 18 b) 28 c) 8 d) 24
15. Based on the line of regression, about how many movies does an average 19-yr. old attend?
 a) 18 b) 28 c) 8 d) 22
16. Five people who all live in the same apartment building have yearly salaries of \$10,000, \$10,000, \$15,000, \$18,000, and \$1,000,000. Which of the following best characterizes the tenants' salaries?
 a) mean b) range c) median d) mode

The following plot is for 40 test scores. Use this plot for questions 17 to 21.



17. Approximately how many test scores are between 64 and 86?
 a) 10 b) 20 c) 22 d) 30 e) 40
18. What is the interquartile range?
 a) 10 b) 12 c) 31 d) 26 e) 22

19. What is the median score?

- a) 54 b) 60 c) 79 d) 82 e) 97

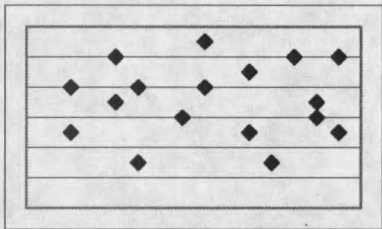
20. What is the third quartile value?

- a) 54 b) 60 c) 75 d) 86 e) 97

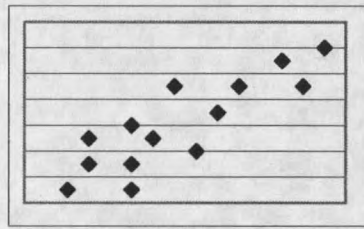
21. What is the minimum score?

- a) 58 b) 60 c) 75 d) 82 e) 97

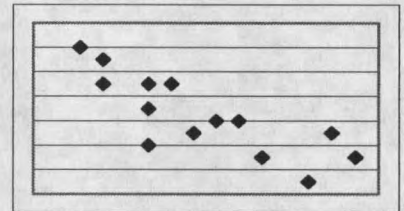
For the following three scatter plots, determine if there is a positive correlation, negative correlation, or no correlation between the variables.



22. a) positive correlation
b) negative correlation
c) no correlation



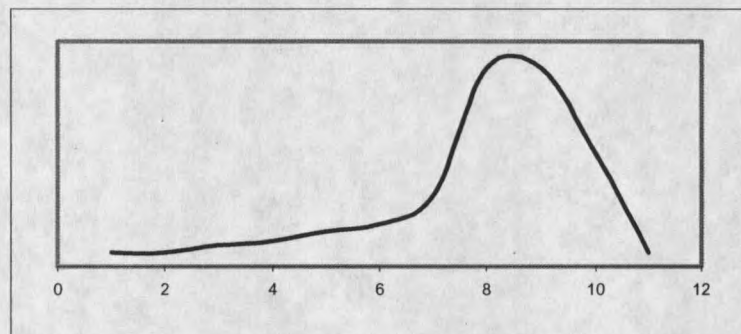
23. a) positive correlation
b) negative correlation
c) no correlation



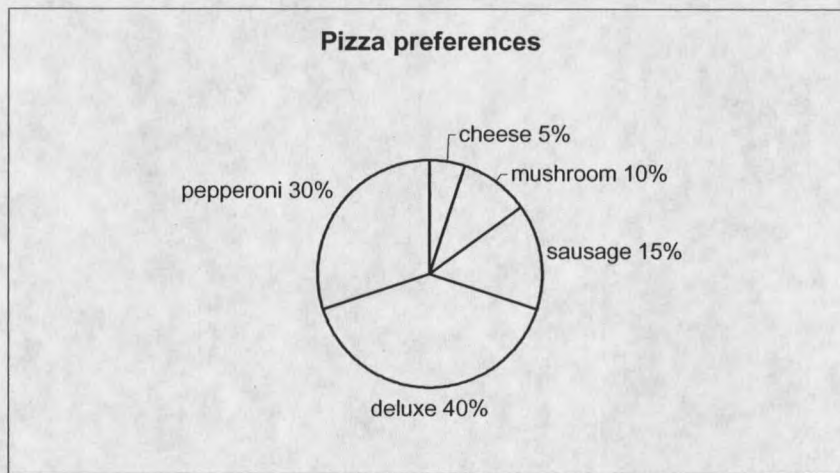
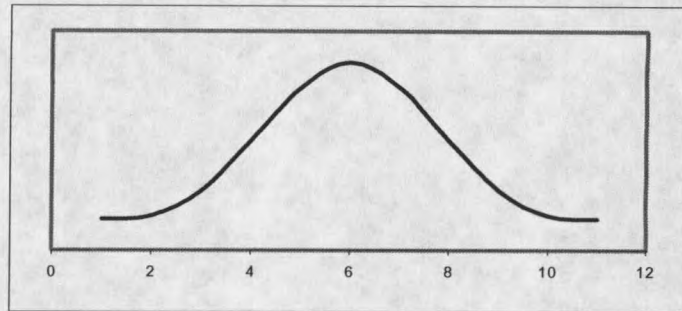
24. a) positive correlation
b) negative correlation
c) no correlation

25. This distribution is

- a) skewed right
b) skewed left
c) symmetric



26. This distribution is
- a) skewed right
 - b) skewed left
 - c) symmetric



27. Which is the most popular pizza?
- a) deluxe b) mushroom c) cheese d) pepperoni
28. How does pepperoni compare to mushroom?
- a) more b) less c) same d) can't tell
29. Which two pizzas make up about half of the preferences?
- a) cheese & mushroom b) sausage & deluxe
 - c) mushroom & deluxe d) mushroom & pepperoni
30. What is the ratio of the size of cheese to mushroom?
- a) 3 : 1 b) 2 : 3 c) 3 : 4 d) 1 : 2

31. If ten people in the survey prefer cheese pizza, what is the approximate total number of people surveyed?

- a) 200 people b) 180 people c) 100 people d) 150 people

Questions 32-38 require a short answer. Write your answers on these pages.

32. The following graph shows the test scores from two classes.

Class A		Class B
1	9	0 4 4 5
9 5 4 2 1	8	2 2 3 5 5 7 9
9 7 6 5 3 3 2 1 1 0	7	0 0 1 2 3 4 4 5 7 8
8 8 7 6 6 4 3	6	2 6 7
5 2	5	7
9	4	5

1 | 9 represents a score of 91 (Class A)
9 | 0 represents a score of 90 (Class B)

Which class appears to have better performance? Explain your answer.

33. Two star running backs each have a 5-yard rushing average.

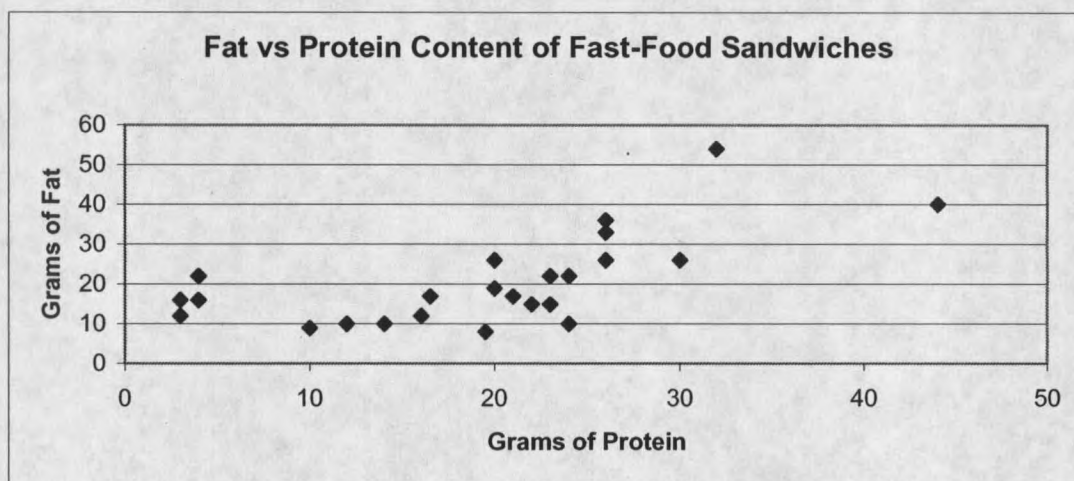
Jones 5 3 5 6 6 4 6 5 5 5 Avg: 5 yd.

Smith 10 2 3 0 15 0 0 5 10 5 Avg: 5 yd.

Which one would you choose to run if you needed three yards on a third-down play late in the game? Why?

35. The personnel director of a company is recruiting employees. In the interview, he tells a candidate that the average salary of the employees is \$32,400. If the company's salaries are as follows, is his claim a fair representation? Explain.

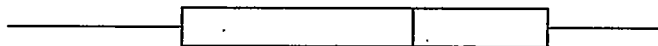
Salary	No. of Employees
\$80,000	1
\$65,000	1
\$49,000	3
\$35,000	16
\$29,500	34
\$20,500	6



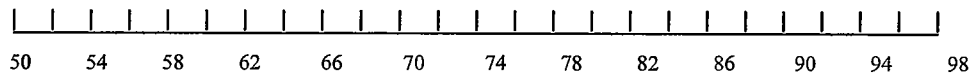
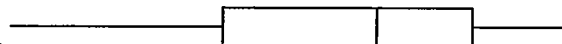
35. Sketch a line of regression to be used to make the following predictions.
36. Use your line of regression to predict the grams of fat in a sandwich with 10 grams of protein.
37. Using your line of regression, how many grams of fat would you expect in a sandwich with 50 grams of protein? _____ What assumptions, if any, did you make?

38. Test score data for two classes are shown in the following graph. Which class did better? Explain.

Class 1



Class 2



39. In what grade did you student teach?

a) Pre-K, K, 1st, or 2nd

b) 3rd, 4th, or 5th

c) 6th, 7th, or 8th

40. Did you teach mathematics during your student teaching experience?

a) Yes b) No

Appendix B
Scoring Rubric for Short Answer Questions

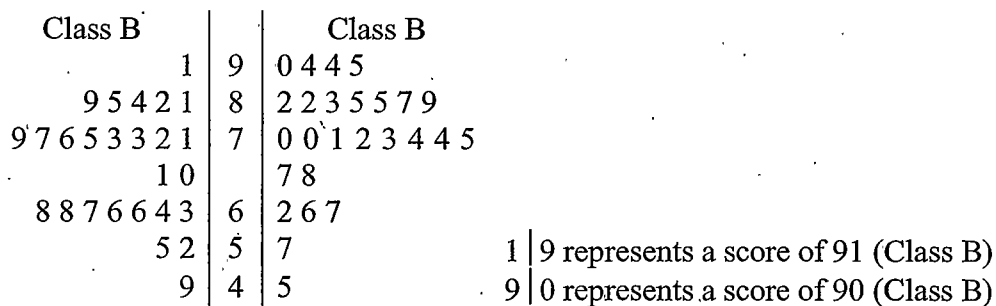
The scoring rubrics all follow the same basic pattern (See table 1). Multiple possibilities exist for some options. The researcher scored the short answers and the appropriate response was marked on individual answer sheets with the letter corresponding to their answer prior to machine scoring.

- a) no answer
- b) wrong answer
- c) right answer, no explanation
- d) right answer, partial /unclear explanation
- e) right answer, complete/clear explanation

Table 1
Basic Pattern for Scoring Rubric

Question 32

The following graph shows the test scores from two classes.



Which class appears to have better performance? Explain your answer.

Scoring rubric for question 32.

- a) no answer or both classes are the same
- b) Class A
- c) Class B no explanation
- d) Class B ,
 - 1) only mentions it has most scores in the 90s;
 - 2) only mentions it has fewer failing grades
 - 3) only mentions mean or median

- e) Class B,
- 1) it has almost twice as many scores above 80 and only one-half as many scores below 70
 - 2) mentions a higher mean (76.8 compared to 71.8) and higher median (76 vs. 71.5)
 - 3) mentions entire stem-and-leaf plot is skewed to higher values

Question 33

Two star running backs each have a 5-yard rushing average.

Jones 5 4 6 7 7 4 6 5 5 5 Avg: 5 yd.

Smith 10 2 3 0 15 0 0 5 10 5 Avg: 5 yd.

Which one would you choose to run if you needed three yards on a third-down play late in the game? Why?

Scoring rubric for question 33

- a) no answer
- b) Smith
- c) Jones, no explanation
- d) Jones,
 - 1) he got yardage every time
 - 2) he gained at least 5 yards all but 2 of the 10 carries shown

Question 34

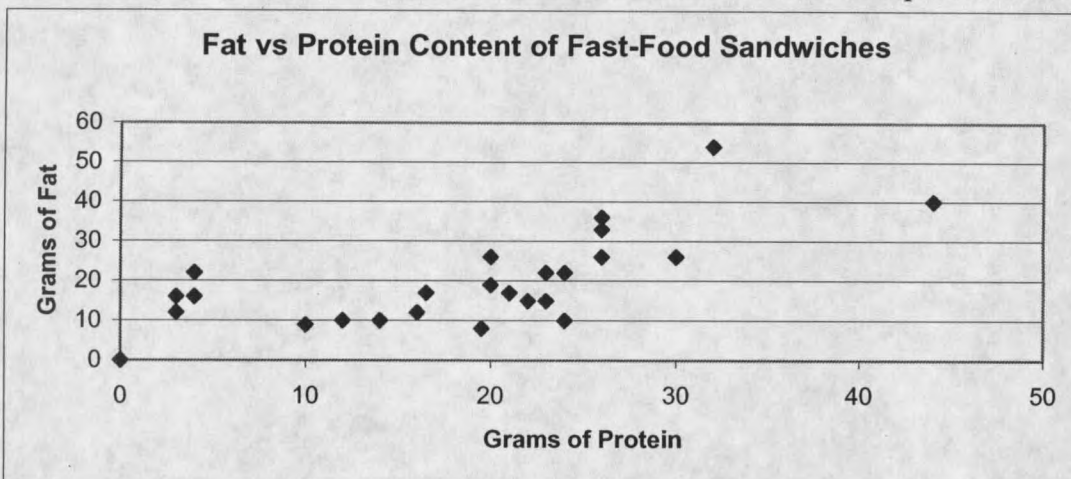
The personnel director of a company is recruiting employees. In the interview, he tells a candidate that the average salary of the employees is \$32,400. If the company salaries are as follows, is his claim a fair representation?

Salary	No. of Employees
\$80,000	1
\$65,000	1
\$49,000	3
\$35,000	16
\$29,500	34
\$20,500	6

Scoring rubric for question 34

- a) no answer
- b) agree with personnel director, mean of \$32,500 is OK
- c) disagree with personnel director's claim, but no explanation why
- d) disagree with personnel director's claim,
 - 1) use either median or mode as explanation
 - 2) say that all starting employees will start at lowest salary

- e) disagree with personnel director's claim,
 1) use median **and** mode as explanation
 2) explain that mean is skewed due to extreme values of top five salaries



Question 35

Sketch a line of regression to be used to make the following predictions.

Scoring rubric for question 35

- no answer
- incorrect line of undetermined reasoning
- line with negative correlation
- positive correlation, but doesn't include all data points
- positive correlation, basically in midst of data points

Question 36

Use your line of regression to predict the grams of fat in a sandwich with 10 grams of protein.

Scoring rubric for question 36

- no answer
- wrong answer according to line drawn
- right answer according to line drawn

Question 37

Using your line of regression, how many grams of fat would you expect in a sandwich with 50 grams of protein? _____ What assumptions, if any did you make?

Scoring rubric for question 37

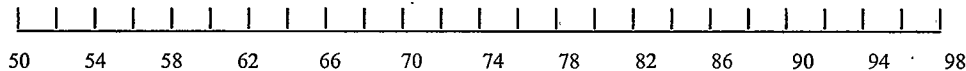
- no answer
- wrong answer according to line drawn
- right answer according to line drawn, no answer to assumption question

- d) right answer according to line drawn
 - 1) no sandwich that high in protein and/or fat
 - 2) stated that they made no assumptions
 - 3) made incorrect assumption
- e) right answer according to line drawn
 - 1) made prediction past range of data
 - 2) assumed that the same line of regression would continue

Class 1



Class 2

**Question 38**

Test score data for two classes is shown in the above graph. Which class did better? Explain.

Scoring rubric for question 38

- a) no answer
- b) Class 1
- c) Class 2,
 - 1) no explanation
 - 2) faulty explanation - mean
- d) Class 2,
 - 1) the highest score is in Class 2
 - 2) Class 1 has the lowest scores
 - 3) range only
- e) Class 2
 - 1) entire box-and-whisker plot is skewed right
 - 2) the median for Class 2 is almost the same value as the third quartile for Class 1, therefore half of the students in Class 2 did better than almost three fourths of the students in Class 1.

Appendix C
Cover Letter to Math Educators and Statisticians
for Test Instrument Form and Content Review

Thank you for agreeing to review the test instrument that I plan to use for my doctoral research. I included the correct answers in red. I have also included the Table of Specifications.

I am going to pilot the test this summer session, so I need to have your recommendations by Monday, May 31. Please make any corrections or suggestions directly on the test instrument. Any additional general comments or concerns can be included on the last page.

I am asking you and others to act as my panel of experts to determine the content validity of the testing instrument.

My research will center on data analysis knowledge among preservice elementary education teachers. Preservice teachers enrolled in four classes within the Elementary Education Program will be tested during Fall Semester 1999. The four classes are MATH 130, MATH 131, EDEL 333, and EDCI 410.

This is the pertinent section of the National Council of Teachers of mathematics (NCTM) Standard 5. Standard 5 is Data Analysis, Statistics and Probability. NCTM, American Statistical Association (ASA), and other professional associations agree that these are the skills that elementary students should have. I intend to test to see if the preservice teachers have the requisite knowledge.

❖ **Interpret data using methods of exploratory data analysis;**

In grades pre-K-2, all students should -

- describe parts of the data and the data as a whole;
- identify parts of the data with special characteristics, for example the category with the most frequent response. (NCTM, 1998 p 130-131)

In grades 3-5, all students should -

- describe the shape and important features of a set of numerical data, including its range, where the data are concentrated or sparse, and whether there are outliers;
- describe the center of sets of numerical data, first informally, then using the median;
- classify and describe categorical data (e.g., ways we travel to school) in different ways; analyze and compare the information highlighted by different classifications;
- compare related data sets, with emphasis on the range, center, and how the data are distributed;
- propose and justify conclusions based on data;
- formulate questions or hypothesis based on initial data collections, and design further studies to explore them. (NCTM, 1998 p 181)

In grades 6-8, all students should -

- find, describe, and interpret mean, median and mode as measures of the center of a data set; know which measure is best to use in particular situations; and understand how each does and does not represent the data;
- describe and interpret the spread of a set of data using tools such as range, interquartile range, and box-and-whisker graphs;
- interpret graphical representations of data, including descriptions and discussion of the meaning of the shape and features of the graph, such as symmetry, skewness, and outliers;
- analyze associations between variables by comparing the centers, spreads, and graphical representations of related data sets;
- examine and interpret relationships between two variables using tools such as scatter plots and approximate lines of best fit (NCTM, 1998 p 238).

Appendix D
Letter to Mathematics Educators and Statisticians
for Content Validity

I have developed the testing instrument that I intend to use for my doctoral research. I am asking you and others to act as my panel of experts to determine the content validity of the testing instrument.

I would like you to do two things for me, please.

1. Review the test instrument to determine if the questions are appropriate;
2. Mark the Table of Specifications to indicate which of the five goal statements the test item most clearly tests.

The five goal statements are taken from the National Council of Teachers of mathematics (NCTM) Standard 5. Standard 5 is Data Analysis, Statistics and Probability. NCTM, American Statistical Association (ASA), and other professional associations agree that these are the skills that elementary students should have. I intend to test to see if the preservice teachers have the requisite knowledge.

My research will center on data analysis knowledge among preservice elementary education teachers. Preservice teachers enrolled in four classes within the Elementary Education Program will be tested during Fall Semester 1999. The four classes are MATH 130, MATH 131, EDEL 333, and EDCI 410.

I am going to pilot the test this summer session, so I would appreciate greatly getting your recommendations by Friday June 18. Please make any corrections or suggestions directly on the test instrument. Any additional general comments or concerns can be included on the last page.

Thank you very much,

- A. find, describe, and interpret mean, median and mode as measures of the center of a data set; know which measure is best to use in particular situations; and understand how each does and does not represent the data;
- B. describe and interpret the spread of a set of data using tools such as range, inter-quartile range, and box-and-whisker graphs;
- C. interpret graphical representations of data, including descriptions and discussion of the meaning of the shape and features of the graph, such as symmetry, skewness, and outliers;
- D. analyze associations between variables by comparing the centers, spreads, and graphical representations of related data sets;
- E. examine and interpret relationships between two variables using tools such as scatter plots and approximate lines of best fit.

#	A	B	C	D	E
5					
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#	A	B	C	D	E
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37					
38					

Appendix E
Curriculum in Elementary Education
Mathematics Option
at Montana State University - Bozeman

Curriculum in Elementary Education Mathematics Option - IAAJ

Name of Student: _____

All mathematics option students are to follow the elementary education K-8 option curriculum, with these exceptions.

Course No.	Core Area	Course Title	Cr.	Semester Taken	Substitution
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DELETE

Electives 12

ADD

EDSD 371		Meth Tch Mid Sch MATH	3	
MATH 150	M	Finite Mathematics	3	
MATH 151	M	Language of MATH	3	
STAT 216		Elementary Statistics	3	
Restricted Electives in Mathematics			6	
Mathematics Electives Recommended				
MATH 110		Trigonometry	3	
MATH 170	M	Survey of Calculus	4	

Note to Advisor: Attach to Elementary Education K-8 Option Program Sheet

Appendix F
Means Tables for Hypotheses

TABLES OF MEANS for Hypothesis 1

Means for interaction of group and gender pertaining to achievement in Overall Achievement

		Total test			
		MATH 130	MATH 131	EDEL 333	EDEL 410
Male		20.6000 (15)	27.8571 (7)	22.2500 (8)	20.333 (6)
Female		19.7576 (66)	25.0294 (34)	24.4118 (51)	21.8222 (45)
		19.9136 (81)	25.5122 (41)	24.1186 (59)	22.3534 (232)

Number shown in parenthesis.

Means for interaction of group and gender pertaining to achievement when finding, describing and interpreting mean, median and mode,

		Sub test #1			
		MATH 130	MATH 131	EDEL 333	EDEL 410
Male		5.2000 (15)	9.0000 (7)	5.6259 (8)	5.5000 (6)
Female		5.115 (66)	7.8824 (34)	7.1176 (51)	6.2222 (45)
		5.1605 (81)	8.0732 (41)	6.9153 (59)	6.1373 (51)

Number shown in parenthesis.

Means for interaction of group and gender pertaining to achievement in interpreting box and whisker plots,

		Sub test #2			
		MATH 130	MATH 131	EDEL 333	EDEL 410
Male		2.6000 (15)	4.4286 (7)	3.6250 (8)	3.1667 (6)
Female		2.7273 (66)	4.0588 (34)	3.9216 (51)	3.3778 (45)
		2.7037 (81)	4.1220 (41)	3.8814 (59)	3.3529 (51)

Number shown in parenthesis.

Means for interaction of group and gender pertaining to achievement in understanding the meaning of the shape and features of a graph,

Sub test #3

	MATH 130	MATH 131	EDEL 333	EDEL 410	
Male	4.6667 (15)	6.0000 (7)	5.1250 (8)	5.0000 (6)	5.0833 (36)
Female	4.6061 (66)	5.2647 (34)	5.3137 (51)	4.6667 (45)	4.9184 (196)
	4.6173 (81)	5.3902 (41)	5.2881 (59)	4.7059 (51)	4.9440 (232)

Number shown in parenthesis.

Means for interaction of group and gender pertaining to achievement in comparing centers, spreads, and graphical representations of related data sets,

Sub test #4

	MATH 130	MATH 131	EDEL 333	EDEL 410	
Male	2.8000 (15)	3.1429 (7)	3.3750 (8)	2.6667 (6)	2.9722 (36)
Female	2.7727 (66)	2.9118 (34)	3.2353 (51)	3.1778 (45)	3.0102 (196)
	2.7778 (81)	2.9512 (41)	3.1176 (59)	3.1176 (51)	3.0043 (232)

Number shown in parenthesis.

Means for interaction of group and gender pertaining to achievement in using scatter plots and lines of best fit.

Sub test #5

	MATH 130	MATH 131	EDEL 333	EDEL 410	
Male	7.5333 (15)	8.8571 (7)	7.7500 (8)	6.8333 (6)	7.7222 (36)
Female	7.1970 (66)	7.9412 (34)	8.1569 (51)	7.3111 (45)	7.6020 (196)
	7.2573 (81)	8.0976 (41)	8.1017 (59)	7.2549 (51)	7.6207 (232)

Number shown in parenthesis.

TABLES OF MEANS for Hypothesis 2

Means for interaction of group and age pertaining to achievement in Overall Achievement

	Total test				
	MATH 130	MATH 131	EDEL 333	EDEL 410	
25 and younger	20.0270 (74)	25.4359 (39)	24.2692 (52)	21.5870 (46)	22.4123 (211)
26 and older	18.7143 (7)	27.0000 (2)	23.0000 (7)	22.2000 (5)	21.7619 (21)
	19.9136 (81)	25.5122 (41)	24.1186 (59)	21.6471 (51)	22.3534 (232)

Number shown in parenthesis.

Means for interaction of group and age pertaining to achievement when finding, describing and interpreting mean, median and mode,

	Sub test #1				
	MATH 130	MATH 131	EDEL 333	EDEL 410	
25 and younger	5.1757 (74)	8.0513 (39)	7.0962 (52)	6.0435 (46)	6.3697 (211)
26 and older	5.0000 (7)	8.5000 (2)	5.5714 (7)	7.0000 (5)	6.0000 (21)
	5.1605 (81)	8.0732 (41)	6.9153 (59)	6.1373 (51)	6.3362 (232)

Number shown in parenthesis.

Means for interaction of group and age pertaining to achievement in interpreting box and whisker plots,

	Sub test #2				
	MATH 130	MATH 131	EDEL 333	EDEL 410	
25 and younger	2.7703 (74)	4.1026 (39)	3.8462 (52)	3.3696 (46)	3.4123 (211)
26 and older	2.0000 (7)	4.500 (2)	4.1429 (7)	3.2000 (5)	3.3281 (21)
	2.7037 (81)	4.1220 (41)	3.8814 (59)	3.3529 (51)	3.3966 (232)

Number shown in parenthesis.

Means for interaction of group and age pertaining to achievement in understanding the meaning of the shape and features of a graph,

Sub test #3

	MATH 130	MATH 131	EDEL 333	EDEL 410	
25 and younger	4.6351 (74)	5.3590 (39)	5.2500 (52)	4.6957 (46)	4.9336 (211)
26 and older	4.4286 (7)	6.0000 (2)	5.5714 (7)	4.8000 (5)	5.0476 (21)
	4.6173 (81)	5.3902 (41)	5.2881 (59)	4.7059 (51)	4.9440 (232)

Number shown in parenthesis.

Means for interaction of group and age pertaining to achievement in comparing centers, spreads, and graphical representations of related data sets,

Sub test #4

	MATH 130	MATH 131	EDEL 333	EDEL 410	
25 and younger	2.7838 (74)	2.9487 (39)	3.2500 (52)	3.1087 (46)	3.0000 (211)
26 and older	2.7143 (7)	3.0000 (2)	3.2857 (7)	3.2000 (5)	3.0476 (21)
	2.7778 (81)	2.9512 (41)	3.2542 (59)	3.1176 (51)	3.0043 (232)

Number shown in parenthesis.

Means for interaction of group and age pertaining to achievement in using scatter plots and lines of best fit.

Sub test #5

	MATH 130	MATH 131	EDEL 333	EDEL 410	
25 and younger	7.3108 (74)	8.0769 (39)	8.0962 (52)	7.3043 (46)	7.6445 (211)
26 and older	6.7143 (7)	8.5000 (2)	8.1429 (7)	6.8000 (5)	7.3810 (21)
	7.2593 (81)	8.0976 (41)	8.1017 (59)	7.3549 (51)	7.6207 (232)

Number shown in parenthesis.

TABLES OF MEANS for Hypothesis 3

Means for interaction of group and degree of high school mathematics preparation pertaining to achievement in Overall Achievement

Total test					
	MATH 130	MATH 131	EDEL 333	EDEL 410	
Basic Preparation	15.4000 (5)	27.0000 (1)	24.5000 (4)	21.2000 (5)	20.5333 (15)
Average Preparation	18.8947 (38)	24.5714 (21)	23.4333 (30)	21.1333 (30)	21.6050 (119)
Advanced Preparation	21.5263 (38)	26.4737 (19)	24.8800 (25)	22.7500 (16)	23.5408 (98)
	19.9136 (81)	25.5122 (41)	24.1186 (59)	21.6471 (51)	22.3534 (232)

Number shown in parenthesis.

Means for interaction of group and degree of high school mathematics preparation pertaining to achievement when finding, describing and interpreting mean, median and mode,

Sub test #1					
	MATH 130	MATH 131	EDEL 333	EDEL 410	
Basic Preparation	3.2000 (5)	9.000 (1)	7.5000 (4)	6.000 (5)	5.6667 (15)
Average Preparation	4.7895 (38)	7.7143 (21)	6.6333 (30)	5.7667 (30)	6.0168 (119)
Advanced Preparation	5.7895 (38)	8.4211 (19)	7.1600 (25)	6.8750 (16)	6.8265 (98)
	5.1605 (81)	8.0732 (41)	6.9153 (59)	6.1373 (51)	6.3362 (232)

Number shown in parenthesis.

Means for interaction of group and degree of high school mathematics preparation pertaining to achievement in interpreting box and whisker plots,

Sub test #2					
	MATH 130	MATH 131	EDEL 333	EDEL 410	
Basic Preparation	2.2000 (5)	4.0000 (1)	4.0000 (4)	3.0000 (5)	3.0667 (15)
Average Preparation	2.3684 (38)	3.8571 (21)	3.8333 (30)	3.3000 (30)	3.2353 (119)
Advanced Preparation	3.1053 (38)	4.4211 (19)	3.9200 (25)	3.5625 (16)	3.6429 (98)
	2.7037 (81)	4.1220 (41)	3.8814 (59)	3.3529 (51)	3.3966 (232)

Number shown in parenthesis.

Means for interaction of group and degree of high school mathematics preparation pertaining to achievement in understanding the meaning of the shape and features of a graph,

Sub test #3					
	MATH 130	MATH 131	EDEL 333	EDEL 410	
Basic Preparation	4.2000 (5)	5.0000 (1)	5.5000 (4)	4.8000 (5)	4.8000 (15)
Average Preparation	4.4211 (38)	5.1429 (21)	5.1667 (30)	4.6333 (30)	4.7899 (119)
Advanced Preparation	4.8684 (38)	5.6842 (19)	5.4000 (25)	4.8125 (16)	5.1531 (98)
	4.6173 (81)	5.3902 (41)	5.2881 (59)	4.7059 (51)	4.9440 (232)

Number shown in parenthesis.

Means for interaction of group and degree of high school mathematics preparation pertaining to achievement in comparing centers, spreads, and graphical representations of related data sets,

Sub test #4					
	MATH 130	MATH 131	EDEL 333	EDEL 410	
Basic Preparation	2.2000 (5)	4.0000 (1)	3.2500 (4)	3.2000 (5)	2.9333 (15)
Average Preparation	2.6842 (38)	2.9048 (21)	3.0667 (30)	3.0667 (30)	2.9160 (119)
Advanced Preparation	2.9474 (38)	2.9474 (19)	3.4800 (25)	3.1875 (16)	3.124 (98)
	2.7778 (81)	2.9512 (41)	3.2542 (59)	3.1176 (51)	3.0043 (232)

Number shown in parenthesis.

Means for interaction of group and degree of high school mathematics preparation pertaining to achievement in using scatter plots and lines of best fit.

Sub test #5					
	MATH 130	MATH 131	EDEL 333	EDEL 410	
Basic Preparation	5.4000 (5)	9.0000 (1)	7.7500 (4)	7.2000 (5)	6.8667 (15)
Average Preparation	7.1842 (38)	8.0000 (21)	7.8667 (30)	7.1667 (30)	7.4958 (119)
Advanced Preparation	7.5789 (38)	8.1579 (19)	8.4400 (25)	7.4375 (16)	7.8878 (98)
	7.2593 (81)	8.0976 (41)	8.1017 (59)	7.2549 (51)	7.6207 (232)

Number shown in parenthesis.

TABLES OF MEANS for Hypothesis 4

Means for interaction of group and number of college math and/or statistics classes taken pertaining to achievement in Overall Achievement

	Total test				
	MATH 130	MATH 131	EDEL 333	EDEL 410	
0 math/stat classes	18.8889 (54)	25.8696 (23)	23.1200 (25)	20.5500 (20)	21.3443 (122)
1 math/stat classes	20.6667 (15)	22.8333 (6)	25.0000 (15)	21.2308 (13)	22.4082 (49)
2 math/stat classes	24.0000 (10)	26.5000 (8)	22.5000 (8)	24.2222 (9)	24.2857 (35)
3 math/stat classes	24.0000 (1)	24.6667 (3)	24.3333 (6)	22.0000 (6)	23.5000 (16)
4 or more math/stat classes	19.0000 (1)	28.0000 (1)	28.8000 (5)	22.3333 (3)	25.8000 (10)
	19.9136 (81)	25.5122 (41)	24.2286 (59)	21.6471 (51)	22.3534 (232)

Number shown in parenthesis.

Means for interaction of group and number of college math and/or statistics classes taken pertaining to achievement when finding, describing and interpreting mean, median and mode,

	Sub test #1				
	MATH 130	MATH 131	EDEL 333	EDEL 410	
0 math/stat classes	4.7222 (54)	8.0435 (23)	6.5600 (25)	5.8000 (20)	5.9016 (122)
1 math/stat classes	5.8000 (15)	7.0000 (6)	7.6667 (15)	5.3846 (13)	6.4082 (49)
2 math/stat classes	6.8000 (10)	9.0000 (8)	5.3750 (8)	7.5556 (9)	7.1714 (35)
3 math/stat classes	6.0000 (1)	7.6667 (3)	6.6667 (6)	6.6667 (6)	6.8125 (16)
4 or more math/stat classes	2.0000 (1)	9.0000 (1)	9.2000 (5)	6.3333 (3)	7.6000 (10)
	5.1605 (81)	8.0732 (41)	6.9153 (59)	6.1373 (51)	6.3362 (232)

Number shown in parenthesis.

Means for interaction of group and number of college math and/or statistics classes taken pertaining to achievement in interpreting box and whisker plots,

Sub test #2

	MATH 130	MATH 131	EDEL 333	EDEL 410	
0 math/stat classes	2.4259 (54)	4.2174 (23)	3.7600 (25)	3.1000 (20)	3.1475 (122)
1 math/stat classes	2.8667 (15)	3.5000 (6)	3.8667 (15)	3.3077 (13)	3.3673 (49)
2 math/stat classes	3.7000 (10)	4.3750 (8)	3.7500 (8)	4.1111 (9)	3.9714 (35)
3 math/stat classes	4.0000 (1)	4.0000 (3)	3.8333 (6)	3.1667 (6)	3.6250 (16)
4 or more math/stat classes	4.0000 (1)	4.0000 (1)	4.8000 (5)	3.3333 (3)	4.2000 (10)
	27.037 (81)	4.1220 (41)	3.8814 (59)	3.3529 (51)	3.3966 (232)

Number shown in parenthesis.

Means for interaction of group and number of college math and/or statistics classes taken pertaining to achievement in understanding the meaning of the shape and features of a graph,

Sub test #3

	MATH 130	MATH 131	EDEL 333	EDEL 410	
0 math/stat classes	4.5000 (54)	5.4783 (23)	5.1200 (25)	4.7000 (20)	4.8443 (122)
1 math/stat classes	4.4667 (15)	5.0000 (6)	5.26667 (15)	4.8462 (13)	4.8776 (49)
2 math/stat classes	5.4000 (10)	5.3750 (8)	5.3750 (8)	4.5556 (9)	5.1714 (35)
3 math/stat classes	5.000 (1)	5.0000 (3)	5.5000 (6)	4.8333 (6)	5.1250 (16)
4 or more math/stat classes	5.000 (1)	7.0000 (1)	5.8000 (5)	4.3333 (3)	5.4000 (10)
	4.6173 (81)	5.3902 (41)	5.2881 (59)	4.7059 (51)	4.9440 (232)

Number shown in parenthesis.

Means for interaction of group and number of college math and/or statistics classes taken pertaining to achievement in comparing centers, spreads, and graphical representations of related data sets,

Sub test #4					
	MATH 130	MATH 131	EDEL 333	EDEL 410	
0 math/stat classes	2.7037 (54)	3.1304 (23)	2.9600 (25)	3.0000 (20)	2.8852 (122)
1 math/stat classes	2.6667 (15)	2.5000 (6)	3.3333 (15)	3.1538 (13)	2.9796 (49)
2 math/stat classes	3.3000 (10)	2.7500 (8)	3.5000 (8)	3.3333 (9)	3.2286 (35)
3 math/stat classes	3.0000 (1)	3.0000 (3)	3.5000 (6)	3.0000 (6)	3.1875 (16)
4 or more math/stat classes	3.0000 (1)	3.0000 (1)	3.8000 (5)	3.3333 (3)	3.5000 (10)
	2.7778 (81)	2.9512 (41)	3.2542 (59)	3.1176 (51)	3.0043 (232)

Number shown in parenthesis.

Means for interaction of group and number of college math and/or statistics classes taken pertaining to achievement in using scatter plots and lines of best fit.

Sub test #5					
	MATH 130	MATH 131	EDEL 333	EDEL 410	
0 math/stat classes	7.0000 (54)	8.3478 (23)	7.8000 (25)	6.6000 (20)	7.3525 (122)
1 math/stat classes	7.4000 (15)	7.5000 (6)	8.2000 (15)	7.6923 (13)	7.7347 (49)
2 math/stat classes	8.2000 (10)	7.7500 (8)	8.0000 (8)	7.6667 (9)	7.9143 (35)
3 math/stat classes	9.0000 (1)	8.0000 (3)	8.3333 (6)	7.3333 (6)	7.9375 (16)
4 or more math/stat classes	8.0000 (1)	9.0000 (1)	9.2000 (5)	8.3333 (3)	8.8000 (10)
	7.2593 (81)	8.0976 (41)	8.1017 (59)	7.2549 (51)	7.6207 (232)

Number shown in parenthesis.

TABLES OF MEANS for Hypothesis 5

Means for interaction of group and whether or not the student is in the Elementary Education Program math option pertaining to achievement in Overall Achievement

Total test

	MATH 130	MATH 131	EDEL 333	EDEL 410	
undecided	20.6970 (33)	25.5000 (2)			20.9714 (35)
Enrolled in math option	24.0000 (1)	26.5000 (6)	27.3750 (8)	21.5000 (2)	26.1765 (17)
Not enrolled in math option	19.2766 (47)	25.3333 (33)	23.5800 (50)	21.5417 (48)	22.2191 (178)
4			25.0000 (1)		25.0000 (1)
5				27.0000 (1)	27.0000 (1)
	19.9136 (81)	25.5122 (41)	24.1186 (59)	21.6471 (51)	22.3534 (232)

Number shown in parenthesis.

Means for interaction of group and whether or not the student is in the Elementary Education Program math option pertaining to achievement when finding, describing and interpreting mean, median and mode,

Sub test #1

	MATH 130	MATH 131	EDEL 333	EDEL 410	
undecided	5.5758 (33)	7.5000 (2)			5.6857 (35)
Enrolled in math option	6.9999 (1)	8.5000 (6)	8.6250 (8)	5.5000 (2)	8.0588 (17)
Not enrolled in math option	4.8511 (47)	8.0303 (33)	6.6400 (50)	6.1042 (48)	6.2809 (178)
4			7.0000 (1)		7.0000 (1)
5				9.0000 (1)	9.0000 (1)
	5.1605 (81)	8.0732 (41)	6.9153 (59)	6.1373 (51)	6.3362 (232)

Number shown in parenthesis.

Means for interaction of group and whether or not the student is in the Elementary Education Program math option pertaining to achievement in interpreting box and whisker plots,

Sub test #2					
	MATH 130	MATH 131	EDEL 333	EDEL 410	
undecided	2.8182 (33)	4.5000 (2)			2.9143 (35)
Enrolled in math option	4.0000 (1)	4.1667 (6)	4.5000 (8)	3.5000 (2)	4.2353 (17)
Not enrolled in math option	2.5957 (47)	4.0909 (33)	3.7800 (50)	3.3333 (48)	3.4045 (178)
4			4.0000 (1)		4.0000 (1)
5				4.0000 (1)	4.0000 (1)
	2.7037 (81)	4.1220 (41)	3.8814 (59)	3.3529 (51)	3.3966 (232)

Number shown in parenthesis.

Means for interaction of group and whether or not the student is in the Elementary Education Program math option pertaining to achievement in understanding the meaning of the shape and features of a graph,

Sub test #3					
	MATH 130	MATH 131	EDEL 333	EDEL 410	
undecided	4.7273 (33)	5.5000 (2)			4.7714 (35)
Enrolled in math option	5.0000 (1)	5.8333 (6)	5.7500 (8)	4.5000 (2)	5.5882 (17)
Not enrolled in math option	4.5319 (47)	5.3030 (33)	5.2000 (50)	4.7083 (48)	4.9101 (178)
4			6.0000 (1)		6.0000 (1)
5				5.0000 (1)	5.0000 (1)
	4.6173 (81)	5.3902 (41)	5.2881 (59)	4.7059 (51)	4.9440 (232)

Number shown in parenthesis.

Means for interaction of group and whether or not the student is in the Elementary Education Program math option pertaining to achievement in comparing centers, spreads, and graphical representations of related data sets,

Sub test #4

	MATH 130	MATH 131	EDEL 333	EDEL 410	
undecided	2.8182 (33)	2.5000 (2)			2.8000 (35)
Enrolled in math option	3.0000 (1)	2.6667 (6)	3.8750 (8)	3.0000 (2)	3.2941 (17)
Not enrolled in math option	2.7447 (47)	3.0303 (33)	3.1600 (50)	3.1042 (48)	3.0112 (178)
4			3.0000 (1)		3.0000 (1)
5				4.0000 (1)	4.0000 (1)
	2.7778 (81)	2.9512 (41)	3.2542 (59)	3.1176 (51)	3.0043 (232)

Number shown in parenthesis.

Means for interaction of group and whether or not the student is in the Elementary Education Program math option pertaining to achievement in using scatter plots and lines of best fit.

Sub test #5

	MATH 130	MATH 131	EDEL 333	EDEL 410	
undecided	7.2727 (33)	8.5000 (2)			7.3429 (35)
Enrolled in math option	9.0000 (1)	8.3333 (6)	8.3750 (8)	7.5000 (2)	8.2941 (17)
Not enrolled in math option	7.2128 (47)	8.0303 (33)	8.0600 (50)	7.02083 (48)	7.6011 (178)
4			8.0000 (1)		8.0000 (1)
5				9.0000 (1)	9.0000 (1)
	7.2593 (81)	8.0976 (41)	8.1017 (59)	7.2549 (51)	7.6207 (232)

Number shown in parenthesis.

TABLES OF MEANS for Hypothesis 6

Means for grade taught during student teaching and whether or not student taught math while student teaching pertaining to achievement in Overall Achievement

Total test				
	PreK-2	3-5	6-8	
Taught math	20.81 (16)	22.46 (24)	22.50 (2)	21.83 (42)
Did not teach math	25.00 (1)		19.00 (6)	19.86 (7)
	21.06 (17)	22.46 (24)	19.88 (8)	21.55 (49)

Number shown in parenthesis.

Means for grade taught during student teaching and whether or not student taught math while student teaching pertaining to achievement when finding, describing and interpreting mean, median and mode,

Sub test #1				
	PreK-2	3-5	6-8	
Taught math	5.69 (16)	6.25 (24)	6.00 (2)	6.02 (42)
Did not teach math	8.00 (1)		5.83 (6)	6.14 (7)
	5.82 (17)	6.25 (24)	5.88 (8)	6.04 (49)

Number shown in parenthesis.

Means for grade taught during student teaching and whether or not student taught math while student teaching pertaining to achievement in interpreting box and whisker plots,

Sub test #2				
	PreK-2	3-5	6-8	
Taught math	3.19 (16)	3.54 (24)	3.50 (2)	3.40 (42)
Did not teach math	4.00 (1)		2.83 (6)	3.00 (7)
	3.24 (17)	3.54 (24)	3.00 (8)	3.35 (49)

Number shown in parenthesis.

Means for grade taught during student teaching and whether or not student taught math while student teaching pertaining to achievement in understanding the meaning of the shape and features of a graph,

		Sub test #3			
		PreK-2	3-5	6-8	
Taught math	Did not	5.00 (16)	4.75 (24)	5.50 (2)	4.88 (42)
	teach math	3.00 (1)		4.00 (6)	3.86 (7)
		4.88 (17)	4.75 (24)	4.38 (8)	4.73 (49)

Number shown in parenthesis.

Means for grade taught during student teaching and whether or not student taught math while student teaching pertaining to achievement in comparing centers, spreads, and graphical representations of related data sets,

		Sub test #4			
		PreK-2	3-5	6-8	
Taught math	Did not	3.06 (16)	3.29 (24)	2.50 (2)	3.17 (42)
	teach math	4.00 (1)		2.50 (6)	2.71 (7)
		3.12 (17)	3.29 (24)	2.50 (8)	3.10 (49)

Number shown in parenthesis.

Means for grade taught during student teaching and whether or not student taught math while student teaching pertaining to achievement in using scatter plots and lines of best fit.

		Sub test #5			
		PreK-2	3-5	6-8	
Taught math	Did not	6.75 (16)	7.71 (24)	7.50 (2)	7.33 (42)
	teach math	9.00 (1)		6.17 (6)	6.57 (7)
		6.88 (17)	7.71 (24)	6.50 (8)	7.22 (49)

Number shown in parenthesis.

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