IMPACT OF *TINKERPLOTS*™ ON PRESERVICE ELEMENTARY TEACHERS' UNDERSTANDING OF MEASURES OF CENTER AND GRAPHICAL REPRESENTATIONS

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Graduate College of the
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in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
July, 2013

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ACKNOWLEDGMENTS

I would like to express my sincere gratitude to several individuals who have helped me achieve my educational goals. First, I would like to thank Dr. Juliana Utley, my dissertation advisor, for providing guidance, wisdom, support, and patience throughout my time at Oklahoma State University. She is a thoughtful, dedicated, and professional educator. Her expertise, advice, and leadership, as well as the immeasurable amount of time spent reading, editing, and revising, have helped learn more about research than I thought possible and have helped me to become a better teacher and stronger researcher.

I would also like to express my genuine thanks to my committee chair, Dr. Patricia Lamphere-Jordan. Whenever I needed encouragement or compassion, she was always ready to provide it. I appreciate her willingness to help me in my research by reading, editing, and suggesting new ideas and perspectives. I appreciate her dedication to mathematics education and her continuing efforts to improve teaching and learning in mathematics, by being a model educator and active researcher, and mentoring mathematics educators like myself.

To committee member Dr. Adrienne Sanogo, I would like to express my thanks for being willing to serve on my committee and assist me in my research by providing new ideas and suggestions, by investing time in reading and editing, and by being an encourager in supporting my work. I count it a privilege to have known her for many years. I admire her dedication to mathematics education and her devotion to becoming a model teacher and researcher. I hope to one day become just as accomplished as she is now.

To committee member Dr. Lynna Ausburn, I would like to thank her for agreeing to serve on my committee and enabling my pursuit of a doctoral degree to begin in an inspired way. She showed me during my first semester in the program at OSU how exciting and wonderful education can and should be. It was my experience in her class that first allowed me to envision the wonderful possibilities that exist in mathematics education. I will never forget that experience.

To committee member, Dr. Douglas B. Aichele, I would like to thank him for agreeing to serve on my committee and enabling me to transform my own educational methods. I appreciate his expertise and his perspective on issues in education, mathematical and otherwise. When I first experienced GeoSET, which he and Dr. John Wolfe created, I realized that he has a unique and valuable vision about mathematics education. I am thankful for his efforts in helping to enhance geometry curriculum and I am appreciative that I have GeoSET available to use in my Mathematics Modeling courses at NSU.

In addition to thanking my committee members, I would also like to convey words of thanks to Dr. Margaret Scott and Dr. Darlinda Cassel. Dr. Scott was instrumental in helping me to begin my journey through the program in an exciting way. She, along with Dr. Ausburn, team taught the very first course I took in the program at OSU. Her fascination, coupled with her realism, allowed me to see an entire spectrum of mathematics education in a new and intriguing way. Dr. Cassel helped me change the way I view teaching and learning. She reinforced the importance of modeling to learn mathematics. She also helped me in presenting research early on in my graduate career. She gave me valuable insight and ideas and she helped me to communicate them in a professional way.

I would also like to thank Dr. Karen Carey for invaluable advice and encouragement. I greatly appreciate her willingness to read, edit, revise, and re-read everything I gave to her. She was always positive and encouraging regarding any criticism of my work. I am grateful that I had her expertise and wisdom to call upon when I was in need. I am also grateful that she was not only willing, but excited to give me any help required.

I would also like to thank Dr. Steven Wilkinson, Dr. Darryl Linde, Dr. Deborah Carment, and Mr. Dan Sisk for their assistance, encouragement, accommodation, and support throughout this process. They provided the help I needed to complete my research in timely and satisfying fashion.

I would also like to express my deepest gratitude to my family. My wife, Sarah, has been amazing throughout the many years of working on this document. She has always been a source of encouragement and peace as I struggled at times throughout the process. Her sacrifices on my behalf have been both beneficial and numerous. I appreciate her support, her love, and her confidence in me. My kids, Zephram, Josie, and Sadie, have also been encouraging and inspiring. I know that they missed time with their father, and I am grateful for their understanding throughout this time. Knowing that they are thinking about me, praying for me, and cheering for me has helped me during the long hours needed to pursue my doctorate.

Finally, I would like to express my thankfulness to Jesus Christ, my Lord. If not for His strength, grace and peace, I would not have been able to reach my goal and complete my work. If not for His salvation, I would not have hope and I would not have life.

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INTRODUCTION

Students are frequently exposed to real-world situations in which they are required to make decisions where a deep understanding of mathematics is needed. In order to be adequately prepared to make informed decisions, students need to be able to think and reason mathematically, which includes being able to think and reason statistically. *Statistical literacy*, which will be more clearly defined later in this document, is an important part of the educational process of students. The National Council of Teachers of Mathematics (NCTM), first in *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989) and then later in *Principles and Standards for School Mathematics* (NCTM, 2000), emphasized the importance of statistics education as a part of the Data Analysis and Probability content standard. They indicated that:

> Instructional programs from pre-kindergarten through grade 12 should enable all students to:
>
> 1. Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them;
> 2. Select and use appropriate statistical methods to analyze data;
> 3. Develop and evaluate inferences and predictions that are based on data.
> 4. Understand and apply basic concepts of probability (NCTM, 2000, p. 48).

Prior to these *Principles and Standards for School Mathematics*, "statistics had been a lost stepchild in mathematics curriculum frameworks, the mere frosting on any mathematics program if there was time at the end of the school year" (Shaughnessy, 2007, p. 957). This tends to no longer be the case. In addition, the NCTM, again in *Principles and Standards for School Mathematics* (NCTM, 2000), describe the Technology Principle, which highlights the importance of using technology in mathematics education:

> Technology can help students learn mathematics….Students' engagement with, and ownership of, abstract mathematical ideas can be fostered through technology. Technology enriches the range and quality of investigations by providing a means of viewing mathematical ideas from multiple perspectives. (NCTM, 2000, p. 25)

Since its introduction, this principle has influenced mathematics instruction in different ways and brought to light various modes of instruction that utilize different kinds of technology. The focus of this study was an investigation of the potential influence of technology on pre-service elementary teachers' level of statistical literacy. This was achieved by looking specifically at two different content areas that are essential for a student to be statistically literate: graphical representations and measures of center. Thus the purpose of this study was to examine the influence of technology, specifically *Tinkerplots™*, on pre-service elementary teachers' understanding of statistics, particularly their understanding of graphical representations and measures of center.

Foundation of the Study

Numerical data and their representations permeate our society in a variety of ways, including news, current events, political trends, finance, social policy and medical reports. Steen (1999) suggested that "[t]he age of information is an age of numbers"(p. 8). However, studies show that students in the United States finish high school failing to meet even minimum expectations for numerical and statistical literacy. Businesses bemoan a shortage of potential employees having skills in quantitative or technical areas. Colleges and Universities are required to offer a wide array of remedial/developmental courses to help offset the numerical deficiencies of incoming students. "Despite years of study and experience in an environment drenched in data, many educated adults remain innumerate" (Steen, 1999, p. 9). *The Mathematics Report Card* (Dossey, Mullis, Lindquist, & Chambers, 1988) provided a picture of the state of numerical and statistical literacy in the United States, by reporting on a sample of seventeen-year-olds who are still in school. Although, most students can adequately perform simple, one-step arithmetic problems like comparing quantities or reading graphs, only half of these students can solve more complicated problems like finding percents or calculating areas. Moreover, less than 10 percent of these students can solve simple multistep problems like calculating a loan repayment or locating the square root of 17 on a number line.

In *Adding It Up: Helping Children Learn Mathematics* (Kilpatrick, Swafford, & Findell, 2001), the authors reported that the research evidence is both consistent and compelling in revealing that U.S. students are weak in mathematical performance. Assessments at the state, national, and international levels indicate that, although students in this country do not fare badly when performing straightforward arithmetical procedures, they demonstrate a limited understanding of mathematical concepts. Furthermore, students are deficient in applying mathematical skills to solve simple problems.

As these quantitative deficiencies have become more apparent, our society's dependence on citizens and workers with quantitative and numerical skills has increased. Globally competitive industries, on which the economy of the U.S. relies, are convinced of the importance of quantitative literacy. It is now expected that entry-level workers exhibit quantitative skills that exceed not only those that are included in vocational or commercial education programs, but also those that are part of most college and university programs (Larson, Guidera, & Smith, 1998). Recent changes in every field around us, particularly the broad use of communication and information technology, cause numerical and statistical literacy to be necessary in all domains to a greater extent than ever before (Lakoma, 2007). Steen (1990) used the analogy "[n]umeracy is to mathematics as literacy is to language" (p. 211) to suggest that both numeracy and literacy are each a unique but critical means to effective communication in any civilized world. However, both literacy and numeracy are in decline in the United States. Even as careers and jobs are requiring more quantitative skills, the workforce is becoming less numerate or numerically literate. What was adequate for numeracy in the past is no longer adequate today (Steen, 1990). If individuals are not numerically literate and not able to think critically about data, then they are unable to participate in any discussion about what numbers mean (Whitin & Whitin, 2008).

Statistical Literacy and Conceptual Framework for the Study

What is meant by statistical literacy? Statistical literacy certainly includes statistical thinking, statistical learning, and statistical reasoning, but there are several other definitions of statistical literacy that appear in statistics education literature. Gal (2002) suggested that statistical literacy includes:

(a) People's ability to interpret and critically evaluate statistical information, data-related arguments, or stochastic phenomena, which they may encounter in diverse contexts, and when relevant,

(b) Their ability to discuss or communicate their reactions to such statistical information, such as their understanding of the meaning of the information, their opinions about the implications of this information, or their concerns regarding the acceptability of given conclusions (pp. 2-3).

Watson, Collis, and Moritz (1997) defined statistical literacy by identifying three components: a basic understanding of statistical terminology, an understanding of statistical language and concepts within the context of social discussion, and the development of a questioning attitude regarding claims that may or may not be made with appropriate statistical foundation. Wallman (1993) defined statistical literacy as the ability to understand and evaluate statistics in our daily lives, as well as an appreciation of how statistical thinking can contribute toward making important personal and professional decisions. Rumsey (2002) offered her own view of statistical literacy when discussing goals for introductory statistics courses. She asserted that students need to be good *statistical citizens*, able to understand statistics sufficiently in order to receive information, think critically about the information, and make decisions based on the information. Rumsey equated statistical literacy with statistical competence. She explained that basic statistical competence involves the following components:

1. Data Awareness,
2. An understanding of certain basic statistical concepts and terminology,
3. Knowledge of the basics of collecting data and generating descriptive statistics,
4. Basic interpretation skills (the ability to describe what the results mean in the context of the problem), and
5. Basic communication skills (being able to explain the results to someone else) (2002, p. 2).

Rumsey also noted that statistical competence is only a beginning and that after students have this basic functional knowledge, they must be able to investigate and think critically on their own. She emphasized that statistical competence is required for statistical thinking and reasoning.

What is meant by statistical thinking or statistical reasoning? These terms are sometimes used interchangeably, but they are in fact the two other arms of statistical development (Chance, 2002). Thus, clearly defining these terms is necessary to help the picture of statistical literacy come into focus. So, what is statistical thinking?

According to Chance (2002), many texts use the phrase *statistical thinking* without giving a formal definition. She explained that many writers will use *thinking*, *reasoning*, and *literacy* interchangeably to distinguish conceptual understanding of statistics from numerical manipulation. This can be misleading. Although statistical thinking includes what a statistician does, like summarizing data, solving problems, reasoning through procedures, and explaining conclusions, it moves beyond those processes. "Perhaps what is unique to statistical thinking, beyond reasoning and literacy, is the ability to see the process as a whole, including 'why,' to understand the relationship and meaning of variation in this process, to have the ability to explore data in ways beyond what has been prescribed in texts, and to generate new questions beyond those asked by the principle investigator" (Chance, 2002, p. 4). As with statistical thinking, many texts use the phrase *statistical reasoning* without explicitly defining what it means, using the term interchangeably with the term *statistical thinking* (Garfield, 2002). The expression is widely used and appears in numerous contexts. Statistical reasoning can be defined as reasoning with statistical ideas or making sense of statistical information (Garfield & Gal, 1999). This definition is helpful, but a more precise one given by Chervaney, Collier, Fienberg, Johnson, and Neter (1977) and Chervaney, Benson, and Iyer (1980) suggests that statistical reasoning is what a student is able to do with statistical content, including recall, recognition, and discrimination among statistical concepts, and the skills that students demonstrate in using statistical concepts in specific problem solving steps. The authors consider statistical reasoning to be a three-step process involving comprehension, which is first, observing similarities that a particular problem has with a specific class of problems. Second is the process of planning and execution, which is solving the problem via suitable and proper methods. The third and final step is evaluation and interpretation, also known as relating the outcome to the original problem (Garfield, 2002).

How are statistical reasoning, thinking, and literacy related to each other? del Mas (2002) answered this question and discussed the similarities and differences that exist between these ideas when commenting on the articles written by Chance, Rumsey, and Garfield, stating, "Each of the papers in this collection identifies one of three overarching goals of statistics instruction. As put forward by the authors, these goals represent our intention, as instructors, to develop students' literacy, reasoning, and thinking in the discipline of statistics" (del Mas, 2002, p. 1).

While it is possible to distinguish between the three goals and associated outcomes, there is significant overlap in these three instructional domains. Two different perspectives are provided by Chance, Rumsey, and Garfield regarding the relationship between these domains. One perspective emerges from focusing on literacy as the development of basic skills and knowledge that are required for statistical reasoning and thinking. This particular point of view considers content in each domain to be independent of the other, accepting some overlap. The other perspective, which holds more closely to opinions held by authors previously cited in this study, is that statistical literacy is an all-encompassing goal of instruction. Statistical reasoning and statistical thinking are no longer considered independent from statistical literacy, but work interdependently to help citizens to become statistically competent (del Mas, 2002).

Although the opinions and theories regarding statistical literacy are numerous and varied, there are several ideas that are common among the authors presented in this section. Thus, a definition of statistical literacy can be generated by focusing on the commonalities that exist. In doing so, a clear and meaningful definition of statistical literacy emerges which is central to this study. For the purpose of this study, *statistical literacy* is defined as the ability to understand statistical terminology, summarize data, solve statistical problems, reason through procedures, explain conclusions, understand statistical measures, understand graphical displays of the data, think critically about results, and generate new questions about the data. Two of the content strands that are a part of statistical literacy—understanding of graphical representations and understanding statistical measures—are the focus of this research study.

The working hypothesis for this study was that technology in the form of statistical software technology would increase pre-service elementary teachers' level of statistical literacy, which would produce an increased understanding of graphical representations and measures of center. Learning styles could potentially influence the effectiveness of statistical software on statistical literacy, but the debate on the influence of learning styles on student learning is ongoing. While an investigation of learning styles is beyond the scope of this study, it is important to note the different opinions regarding the influence of learning styles in an educational setting. According to Coffield, Moseley, Hall, & Ecclestone (2004), learning style researchers are not unified in their opinions regarding the educational effects of learning styles. There is no definitive answer to whether a teaching style should be consistent with learning style.

While Dunn, Beaudry, & Klavas (2002) and Schroeder (1993) claimed that learning styles have a definitive influence on student learning, Garton, Spain, Lamberson, & Spiers (1999) disagree with this claim. They asserted that learning styles had little to no influence on either the achievement or learning perceptions of students. This conceptual framework, including the potential learning styles filter, is shown in Figure 1.

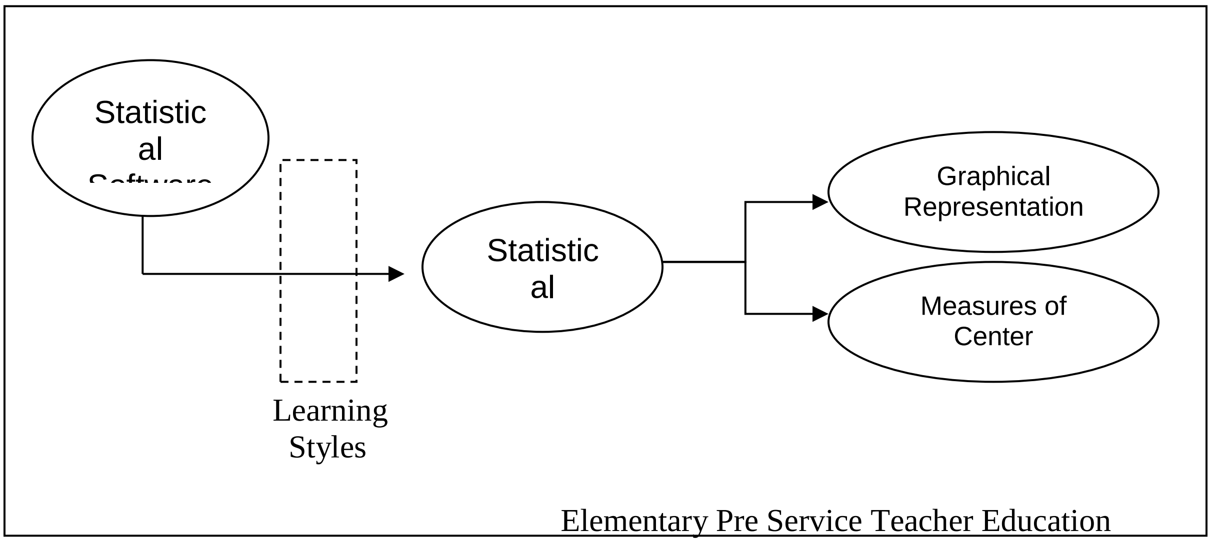


Figure 1. Conceptual Framework for this study

Statement of the Problem

"There are among those responsible for the education of our citizens many who understand fully the importance of promoting statistical literacy…..Most of all, I think of the teachers in our nation's elementary and secondary schools who are working so hard to bring quantitative literacy to their students" (Wallman, 1993, p. 3). In this quote, Wallman points out that educators understand the importance of developing statistically literate students. Statistical literacy is necessary for understanding our data rich society. Because numerical literacy has become vital in work and life, it now plays an important role in education (Steen, 1999). However, as educators will argue, most individuals are not critical readers or analyzers of data they encounter on a daily basis (Whitin & Whitin, 2008). One reason for this is that all aspects of statistical literacy are not uniformly included in traditional school mathematics curricula (Steen, 1990). Although many mathematical and statistical skills which are used in routine daily tasks can be taught in the primary grades, "traditional elementary school curricula have concentrated on arithmetic to the exclusion of most other topics" (Steen, 1990). Moreover, there is little or no reinforcement of statistical proficiency at home or at school. So neither teachers nor parents are emphasizing the importance of statistical literacy. Therefore students are not learning how to become statistically literate.

So what needs to happen? "The proper question is not whether to have more or less of an outmoded and ineffective tradition, but whether is it possible to do better with more effective school practice" (Steen, 1990, p. 224). Since the statistical skills needed to be statistically proficient can be taught in the primary grades, a logical place to start would be the elementary school. An examination of pre-service elementary teachers' level of statistical literacy is important because of their vital role in society, particularly in the information age. However, examining statistical literacy as a whole is beyond the scope of this study. Therefore, this study investigated two vital parts of statistical literacy: graphical representations of data and measures of center. It is also important to investigate the educational effectiveness of statistical software on pre-service elementary teachers' understanding of statistics. One such software package developed in 2004 by Clifford Konold and Craig D. Miller is *Tinkerplots*™, a dynamic data exploration software package for grades four through eight. Although some research on the instructional effectiveness of this and other similar software has been conducted, more research is needed because the software has only been available for use in the last few years, and this type of dynamic software is becoming more prevalent in the classroom. This study opens a line of further research on the effectiveness of emerging software for statistical literacy training.

Purpose of the Study

The primary purpose of this study was to determine through both qualitative and quantitative methodology whether the use of *Tinkerplots*™ in a mathematics modeling classroom influenced pre-service teachers' level of understanding of data analysis. In particular, the study investigated the influence that the use of *Tinkerplots*™ had on pre-service teachers' understanding of how to appropriately select, use, and make informal inferences from both graphical representations of data and measures of center. With this information, teachers may be able to offer their students an alternative approach to learning statistical concepts.

The research questions guiding this study were:

1. How does the use of *Tinkerplots*™ influence preservice elementary teachers' understanding of graphical representations of data (i.e. selection, use, and ability to make inference)?
2. How does the use of *Tinkerplots*™ influence preservice elementary teachers' understanding of measures of center (i.e. selection, use, and ability to make inference)?

Assumptions

Two assumptions were made regarding this study. First, students who participated in assessments, questionnaires, and interviews did so to the best of their ability. Second, each participant responded honestly and thoughtfully to all questions.

Limitations

The first limitation concerns the use of a purposive sample. There are more than two sections of this particular mathematics modeling course offered by the university in the semester, two of which were taught by the same instructor. Thus, it was logical to use those two sections as a sample, one serving as a control group and the other as an experimental group. Since this was a purposive sample, the study's external validity was negatively affected and quantitative findings may not be generalized to the entire population of students. Another limitation in this study was that in using only sections taught by one instructor, data were gathered from only students who preferred this instructor over the other two on campus that teach this course, which may have affected the study's internal validity and skewed the results. Also, the classroom itself did not allow for computer stations, so students had to do work with *Tinkerplots*™ in the computer lab. This was a limitation in that student movement between the classroom and the lab allowed for distractions and interruptions of the learning process. Also, the physical design of the computer lab did not encourage an optimum collaborative learning environment.

Definitions of Terms

<u>Statistical Literacy</u>: Statistical literacy is the ability to: understand statistical terminology, summarize data, solve statistical problems, reason through procedures, explain conclusions, understand statistical measures, understand graphical displays of the data, think critically about results, and generate new questions about the data.

<u>Statistical Thinking</u>: Statistical thinking is the ability to see statistical processes as a whole, including the "why" of statistics. Statistical thinking involves an ability to explore data in unexpected ways and generate new questions.

Statistical Reasoning: Statistical reasoning involves what a student is able to do with statistical content knowledge. This includes interpreting statistical concepts and demonstrating skills that enable problem solving

Data Analysis: Data analysis is the NCTM standard regarding students' ability to formulate questions that can be addressed with data; collect, organize, and display relevant data to answer those questions; select and use appropriate statistical methods to analyze data; and develop and evaluate inferences and predictions that are based on data.

Tool: A tool is a product of cultural history, including technology, developed to support problem solving.

Statistical Software: Statistical software consists of a suite of different computer programs designed for statistical analysis.

Tinkerplots™: *Tinkerplots*™ is a dynamic data exploration software package for grades 4-8 produced by Key Curriculum Press.

Graphical Representations: Graphical representations are visualization representations of data sets including, but not limited to, bar charts, pie charts, line plots, and scatter plots.

Measures of Center: Measures of center are numerical values at the center of a data set including, but not limited to, mean, median, and mode.

Organization of the Dissertation

This study is presented in a five-chapter format. The current chapter provides a general overview including the foundation of the study, a definition of statistical literacy for this study, the purpose of the study, assumptions and limitations, and definitions of terms that were used throughout the study. Chapter two discusses the pertinent literature and previous research related to the role of technology in education, the importance of fundamental mathematical content knowledge and statistical literacy, and how students learn statistics. Chapter three presents the methodology that was used in the study: sampling techniques, an explanation of each instrument, a discussion of how the study was implemented, and the type of statistical procedures used. First, an explanation of how the sample subjects were selected is included, along with a brief description of the characteristics of the sample. Second, chapter three addresses and includes an explanation of each instrument chosen to be used in the study. Those instruments include pre- and post-questionnaires, pre- and post-assessments, pre- and post-concept maps, and interviews of subjects. Finally, chapter three includes a discussion of how the study was conducted, including the types of statistical procedures used and how the statistical results were analyzed.

Chapter four presents the results of the analyses. Chapter five presents the interpretation of the data, the summary, conclusions, implications and recommendations.

CHAPTER TWO

REVIEW OF THE LITERATURE

The purpose of this study was to determine through both qualitative and quantitative methodology the influence of *Tinkerplots*™ software on pre-service elementary teachers' level of understanding of graphical displays and measures of center. With this information, teacher educators may be able to offer their pre-service teachers an alternative approach to learning concepts. The research questions that guide this study were:

1) How does the use of *Tinkerplots*™ influence preservice elementary teachers' understanding of graphical representations of data (i.e., selection, use, and ability to make inference)?

2) How does the use of *Tinkerplots*™ influence preservice elementary teachers' understanding measures of center (i.e., selection, use, and ability to make inference)?

The major areas guiding this study include how students learn, the importance of mathematical content knowledge, the importance of statistical literacy, and the importance of technology's role in mathematics and statistics education. Each section in this chapter discusses a major area in order to help the reader understand where this study fits in body of general mathematics education research. The first section of this chapter discusses the different ways that students learn. What follows in the next two sections is a description of the importance of mathematical content knowledge for students and, more narrowly, a description of the importance of mathematical content knowledge for teachers, because the population of interest in this study was pre-service elementary teachers. Because statistical literacy is an important part of mathematical content knowledge, the fourth and fifth sections discuss statistical literacy for students and teachers, respectively. This leads into a review in the next two sections of technology, and its effective use, in mathematics and statistics education. Finally, the last section of the chapter narrows the focus of the discussion to *Tinkerplots™* influence on statistics learning.

How Students Learn

In 1998, the National Research Council released the report *How People Learn*, which integrates different research on human learning. Research in the report has implications for how our society educates, including curriculum design and learning environments. Bransford, Donovan, and Pellegrino (1999) highlighted three major findings in the report. First, students come into the classroom with preconceived ideas about the world. If educators do not engage this initial understanding, then students may be unable to grasp new concepts and ideas presented in a classroom, or students will only learn them for an assessment and revert to preconceptions when they leave the classroom. Thus, teachers must be prepared to draw out students' existing knowledge and help transform them into knowledge that reflects concepts in the particular discipline of study. Second, to develop competence in an area of learning, students need a deep foundation of factual knowledge along with a strong conceptual framework. The factual information is insufficient in itself. Mastery of concepts that promote deeper understanding is the key to expertise. This allows for the transformation of a set of facts into usable knowledge. The conceptual framework assists professionals in organizing information into meaningful patterns and storing it for later retrieval. Third, teaching strategies can be utilized that will allow students to monitor their own level of understanding and progress. In problem solving, students can consider alternatives and are aware of whether a chosen strategy is leading to the desired end.

According to Kolb & Kolb (2005), these findings are reflective of the six propositions that define experiential learning theory which draws on the works of many prominent 20th century education scholars like John Dewey, Jean Piaget, and Carl Jung. First, learning should be defined in terms of a process, rather than outcomes. Second, all types of learning involves relearning. Third, learning is dependent on resolving conflicts between opposite modes of adaptation to the environment. Fourth, learning is holistic and a process of environmental adaptation. Fifth, learning is the result of successful synergy between the person and their environment. Sixth, learning is a knowledge creating process. "The enhancement of experiential learning…can be achieved through the creation of learning spaces that promote growth-producing experiences for learners" (2005, p. 205).

An understanding of how students learn is both vital and beneficial when investigating how students learn and understand specific content areas, including statistical concepts. Roseth, Garfield and Ben-Zvi (2008) emphasized that instruction in statistics should resemble statistics in practice, where collaboration and cooperation in problem solving is evident. Statisticians often work and communicate with colleagues in the workplace with no statistical background, and teachers should be prepared for this. Statistics educators need to rely less on lecturing and more on alternative approaches like group projects, problem solving and lab activities. Expanding on the value of this learning practice, Roseth et al. (2008) gave six reasons that collaborative teaching is beneficial for statistics education. First, collaboration allows for more accomplishments at a higher level. Second, collaboration promotes reflection on work and questioning of ideas. Third, collaboration motivates and supports necessary changes. Fourth, collaboration allows for consistency within the course. Fifth, collaboration promotes the idea of community. Sixth, collaboration provides guidance and encouragement for new educators. Collaborative education strategies allow for educators to move to a more student-centered mode of instruction. Petocz and Reid (2001) enhanced this perspective, pointing out that this way of experiential learning moves from a disjointed conception involving lectures and required activities designed for simply achieving a passing grade in a class to a more holistic conception focused more on developing statistical understanding. In addition, statistical simulations can be an effective instructional tool when teaching statistics (Chance & Rossman, 2006). Simulations allow students to experience this holistic conception in their statistics course. To further this argument, Nickerson (1995) gave the following helpful guidelines for enhancing instruction via simulation:

- Learning should be a constructive process involving exploration and discovery.
- Simulations can be used to focus students' attention on previously unnoticed aspects of a problem.
- Simulations provide a learning environment where students can express ideas freely and be encouraged via understanding.

Students' Mathematical Content Knowledge

The Third International Mathematics and Science Study (TIMSS), conducted in the mid-1990s, detailed differences in mathematics education of students in U.S. and higher-achieving students from other countries. Although reasons for the mathematical deficiencies in the U.S. at that time were numerous and varied, it was clear that students in the U.S. were not achieving mathematical understanding at an acceptable rate when compared to other countries (Beaton, et al., 1996). In the TIMSS 2003 International Mathematics Report, it was reported that fourth grade and eighth grade students in the United States were performing better in mathematics, in fact both groups scored above the international average. However, the U.S. still ranks substantially below the international leaders. Also, certain segments of the population are not represented by those who do succeed in mathematics. Some individuals are unable to participate fully in society because of the lack of an understanding of basic mathematics (Mullis, Martin, Gonzalez, & Chrostowski, 2004).

In *Adding It Up: Helping Children Learn Mathematics*, Kilpatrick, Swafford, & Findell (2001) addressed these concerns and other issues relating to school mathematics from pre-kindergarten to the eighth grade. They stressed the importance of every young American needing to learn how to think mathematically, and then use mathematical thinking skills to aid the entire learning process. They also noted that students have a limited understanding of basic mathematical concepts and are notably deficient in their ability to apply mathematical skills to solve even simple problems. The overriding premise is that all students be mathematically proficient. Mathematical proficiency is described as having five interwoven and interdependent strands:

- Conceptual understanding is the comprehension of mathematical concepts, operations, and relations.
- Procedural fluency is the skill in carrying out procedures flexibly, accurately, efficiently, and appropriately.
- Strategic competence is the ability to formulate, represent, and solve mathematical problems.
- Adaptive reasoning is the capacity for logical thought, reflection, explanation, and justification.

- Productive disposition is the habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy. (Kilpatrick et al., 2001, p. 4)

It is vitally important for young people to understand the mathematics they are learning, in whatever context. Individuals who are unable to think mathematically can be excluded from many kinds of human endeavor. Kilpatrick et al. (2001) urged researchers who are concerned with mathematics in the school to frame questions that encompass the goal of developing mathematical proficiency for all students. This means that students understand mathematical and statistical ideas, know how to solve problems, and are able to engage in logical reasoning. “They believe they can make sense out of mathematics and can use it to make sense out of things in their world. For them mathematics is personal and is important to their future” (Kilpatrick et al., 2001, p. 409).

Teachers’ Mathematical Content Knowledge

Ball, Lubienski, & Mewborn (2001) claimed that it is obvious, even trivial, when asserting that teacher mathematical knowledge is a vital resource for teaching. Educators understand that what a teacher knows will influence how students learn in the classroom (Fennema & Frank, 1992). The issue of teacher knowledge is not a new one and is much discussed when considering any reform of mathematics teaching and learning. The book *Knowing and Teaching Elementary Mathematics,* by Liping Ma (1999), has been instrumental in spurring discourse and renewed interest in the issue of teacher mathematical content knowledge as a resource for instruction. In her book, comparing U.S. and Chinese elementary teachers’ mathematical knowledge, Ma introduced and developed the notion of a profound understanding of mathematics that includes depth, connectivity, and coherence of basic mathematical properties. Research mathematicians were surprised when they realized how important teachers' mathematical knowledge is when considering effective teaching. According to Ma (1999), "the quality of teacher subject matter knowledge directly affects student learning" (p. 125). This idea is reinforced by Darling-Hammond (1996) in *What Matters Most: Teaching for America's Future*. The report asserts that what teachers know and do will have the greatest effect on student learning. Ball et al. (2001) expanded this idea by stating that what ultimately matters is not only the mathematics that a teacher knows, but also how the teacher is able to use that mathematical knowledge in the course of their work of teaching. Teachers must be able to puzzle about mathematics in an unforeseen way or from a new perspective. They must be comfortable changing problem parameters, using student ideas, and considering multiple representations of a mathematical issue. Ball et al. (2001) referred to this kind of mathematical content knowledge as "*pedagogically useful mathematical understanding"* (p. 453). Hill, Rowan, & Ball (2005) referred to this type of mathematical content knowledge as *mathematical knowledge for teaching*, which means mathematical knowledge that is required to perform the work of teaching mathematics. In their analysis, they discovered that teachers' mathematical knowledge for teaching can positively predict student improvement in mathematics in grades one and three.

Baumert et al. (2010) expanded the investigation of this type of knowledge further by looking at the effect of *pedagogical content knowledge* of teachers on student learning. They concluded that pedagogical content knowledge has a substantial influence on the cognitive structure of learning opportunities in mathematics. Lee Shulman (1987) also emphasized the importance of pedagogical content knowledge when stating that there exists a powerful relationship between teacher comprehension and teaching style. In his words, "teaching behavior is bound up with comprehension and transformation of understanding" (Shulman, 1987, p. 18). Grossman (1995) reinforced this idea when claiming that a teacher who is uncomfortable with course content will often press on through material without allowing for student interactions or questions. This lack of content knowledge restricts and limits her method of teaching.

While addressing concerns regarding the mathematical knowledge deficiency of students in the United States, Kilpatrick et al. (2001) also highlighted the importance of teacher mathematical content knowledge in student mathematical understanding. Children start to learn mathematics before they enter the primary grades. It is important to continue to build on this mathematical content knowledge after children enter the school. Preparation of elementary school teachers in the U.S. often fails to equip them with the necessary mathematical and statistical knowledge needed for helping students develop mathematical proficiency. Although children bring a certain amount of mathematical knowledge with them to the classroom, most of the mathematics they know is learned in the classroom and depends greatly on the individuals who teach it to them.

Since mathematical proficiency is the overall goal for each student and a student's performance at the end of elementary school is a predictor of their ultimate educational success (Kilpatrick et al., 2001), then it is of equal importance that classroom teachers be mathematically proficient themselves. The improvement of student learning depends on the abilities of teachers in the classrooms. Teachers need to understand the mathematics they teach. Effective teacher education programs are designed to help teachers achieve this necessary mathematical proficiency. Teachers play a pivotal role in the mathematical development of the children they teach. How effective a teacher is in mathematics teaching is directly related to the teacher's own mathematical knowledge and engagement with students on mathematical tasks (Kilpatrick et al., 2001). Add to this the expectations of the teacher for the students and the mathematics they are able to learn, as well as the influence the teacher has on this learning, and one can see how vital it is for the teacher to be mathematically proficient. In emphasizing the need for teachers to have a profound understanding of fundamental mathematics (PUFM), Ma (1999) concurred. Ma stated that a teacher with PUFM is able to highlight and integrate the connections between different mathematical concepts and procedures. She has a fundamental understanding of the entire elementary mathematical course curriculum and is able to investigate, revisit, and reinforce powerful mathematical ideas. She is able to see from different perspectives, appreciate new ideas, and engage her students in profound mathematical learning.

Statistical Literacy for Students

In the *Guidelines for Assessment and Instruction in Statistics Education (GAISE) Report*, Franklin et al. (2007) identifed the ultimate goal for every high school graduate in the United States to be statistical literacy. Since our lives are number driven, each high school graduate should be able to reason statistically in order to logically cope with the issues involved with family, career, and social function. It is important for individuals to understand the role statistics plays in their lives. Statistics are used by our government to determine what programs are necessary and how to spend federal monies. Daily personal choices are affected by statistics, whether it is transportation routes, medical treatments, or grocery shopping. Individuals who are adequately prepared to utilize statistical reasoning in their career field will have more opportunities for advancement. Furthermore, a statistically competent workforce in the U.S. will allow for more global competitiveness. Statistics also plays a prominent role in scientific discovery and progress. Statistical literacy can help to promote a healthy skepticism about scientific discoveries. Thus statistical literacy is an essential part of our personal lives as citizens, professionals, and consumers.

Over the last 25 years, statistics has become a key component of mathematics curriculum. The National Council of Teachers of Mathematics (NCTM) produced the influential document *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989) which included Data Analysis and Probability as a content strand. This strand was again highlighted and emphasized in *Principles and Standards for School Mathematics* (2000). The National Assessment of Educational Progress was developed using the same content strands as the NCTM standards, with data analysis problems playing a prominent role on the NAEP exam (Reese, 1997). Additionally, The College Board released its *College Board Standards for College Success: Mathematics and Statistics* in 2007. Data and Variation are included in the list of eight topic areas considered to be central to skills and knowledge developed in middle school and high school grades. Data Analysis is also included in the recent Common Core State Standards for Mathematics in Oklahoma (2010). Thus, the importance of data analysis and statistics is being consistently emphasized and highlighted at every course level.

Statistical thinking should be introduced in the elementary grades and reinforced throughout the academic career of each student. The statistical knowledge required by a student cannot be encompassed by a single course. Data analysis should be integrated into the mathematics curriculum as early as pre-kindergarten. Statistics, however, is a relatively new subject for many teachers. Nicholson and Darnton (2003) stated that Data Analysis is now an integral part of a national mathematics curriculum, and that it requires a different approach from both educators and students. They claimed that this is problematic if a teacher has not studied statistics as part of a course of study, or is not a subject specialist. So it is vital that educators are confronted with the importance of statistical thought, so as to allow for that thought process to begin and continue in the classroom. The designs of data collection, data exploration, and interpretation of results need to be emphasized in any statistical education program for statistical literacy to be achieved (Franklin et al., 2007).

Data analysis is an integral part of statistical literacy, which in turn, is an integral part of numeracy. Although numeracy and literacy are the two most important literacies of our current age, numeracy is the greater challenge. According to Steen (1990), for every individual who cannot read, there are a hundred individuals who are not good at math, and proud of it. This imbalance is troublesome considering we live in an age of data, computers and statistics. It is vitally important, not only for students, but also for citizens, to understand data analysis in order to become statistically literate—or numerate. "Numeracy provides the ability to plan, to challenge, and to predict; it reveals the power of reason and unlocks the language of nature" (1990, p. 229).

The study of statistics is an integral part of a student's educational experience because students will be exposed to data represented in a variety of ways, and they need to be able to effectively read and interpret the data they see. However, according to statistics educators, this is not happening satisfactorily. delMas, Garfield, and Chance (1999) perceived that too many of their students only develop a shallow, isolated understanding of basic statistical concepts. They are concerned that even if a student passes a statistics course, they do not have an in-depth understanding of the concepts to apply them meaningfully to their reasoning. Equipping students with the necessary knowledge and tools to deepen this statistical understanding is one reason the National Council of Teachers of Mathematics created its Data Analysis and Probability Standard, giving statistics the same importance as algebra and geometry. Mathematics educators have come to the realization that statistical literacy is a required ingredient for mathematical literacy. Students cannot be numerically literate if they are not statistically literate. However, statistics topics are often left out of the common mathematics course, shortchanging the student (Rubin, 2005). If educators wish to enable their students to be statistically literate and give data analysis the attention called for by the NCTM, then they must introduce data analysis into their math courses in a seamless and non-intrusive way. If successfully done, statistics will be viewed as an integral part of the mathematical whole instead of an extra ingredient added onto the end.

The increased attention given by business, industry, and government to probability and statistics over the past two decades requires students to have a clearer understanding of statistical concepts now more than ever before. This need for statistical literacy has been echoed by the recommendation of the NCTM (1989, 2000) that data analysis play a prominent role in school mathematics. Recent results from the National Assessment of Educational Progress (NAEP) indicated that not only is more attention being given to data analysis in school mathematics, but also that student performance is gradually improving. Although this is certainly a positive trend regarding statistics education, there are still many students who do not have a clear understanding of statistical concepts. Statisticians are calling on statistics educators to focus their teaching efforts on statistical thinking. In their opinion, the traditional method of teaching statistics, which focuses on skills, has not produced in students an ability to think statistically. Confusion still remains regarding the meaning of measures of center, creation and interpretation of graphs, and recognition of patterns. Students are uncertain of the meaning of median and unsure of which measure of center (mean or median) is appropriate for a given distribution of data (Zawojewski & Shaughnessy, 2000). Students are unaware of the relative advantages or disadvantages of certain graphical representations of the same set of data (Shaughnessy &

Zawojewski, 1999). Students are also unable to choose the best model for a given set of data or see patterns in distributions and spreads (Shaughnessy & Pfannkuch, 2002). One reason for this confusion is that data analysis has only recently been included with other mathematical content areas as equally important in school mathematics. Another reason, tied to the first, is that students too often will learn *how* to calculate statistical measures without understanding *why* they did it or the impact of such analysis. "The source of the difficulty appears to be that students' knowledge often seems limited to computational formulas, and many simple problems require more general, relational knowledge of concepts" (Pollatsek, Lima, & Well, 1981, p. 202).

Student understanding of statistical concepts is lacking when instruction regarding said concepts is limited to calculations without including why the calculations are found and where they are most useful. Research completed by Mokros and Russell (1995) regarding the concept of "average" reinforced the importance of understanding the *why* behind the statistical concept. In their studies, they give five different approaches to solving problems dealing with averages: 1) average as mode, 2) average as algorithm, 3) average as reasonable, 4) average as midpoint, and 5) average as balance point. The students who understood the *why* behind finding an average, the idea of representativeness, are more prepared to use an average, as well as other statistical measures, in correct and useful ways. This approach of not only how, but also why, data is collected and explored is important for students to understand as they are being introduced to statistics (Konold & Pollatsek, 2002) "The big questions in all statistical analyses are: how much can we go beyond the data, and how sure are we of what we then say?" (Rubin, 2005, p. 23).

Statistical Literacy for Teachers

First, an examination of pre-service elementary candidates' statistical literacy is important because these students need to minimize their vulnerability in the computer age. In other words, they need to be able to independently analyze information that they may be exposed to from day to day. Steen (1997) claimed that as information becomes more and more quantitative in nature, and as individuals in society begin to rely increasingly on computers and digital data, an innumerate citizen today is as vulnerable as an illiterate peasant in the fifteenth century, when the printing press was invented. The printing press took power away from those who could not read and placed restrictions on the illiterate. Similarly, computers and digital networks take power away from those who cannot quantify, and places restrictions on the innumerate (Steen, 1997). Pre-service elementary teachers are empowered by being statistically literate and not overly dependent on other sources for data analysis. "Ironic, and at times frightening, is the fact that the same public who has little knowledge about the analysis and interpretation of social and economic data has simultaneously vastly increased access to statistical data and to computing tools that enable virtually anyone to manipulate information" (Wallman, 1993, p. 4). Ridgway, Nicholson, and McCusker (2011) contended that teachers frequently come from a non-quantitative tradition and do not feel confident in their abilities regarding quantitative methods. Furthermore, since statistics requires individuals to make sense of quantitative information in context, it is important for teachers' confidence in this area to be enhanced. Statistically literate pre-service elementary teachers will be more confident and less vulnerable to misinformation or misguided analysis.

Second, an examination of statistical literacy is important because pre-service elementary teachers need to be responsible citizens. We are faced with the realization that there is a growing relationship between statistics and decisions regarding public policy (Wallman, 1993). If citizens desire to influence policy decisions for the good of society, then they must be statistically literate. Steen claimed that if the public is unable to reason with figures, then it unable to discriminate what is rational and what is reckless regarding public policy. Too often, citizens are required to evaluate information that, due to a lack of statistical literacy, they are unable to handle (Wallman, 1993). In the American Statistical Association's *Guidelines for Assessment and Instruction in Statistics Education (GAISE) Report* (2007), Franklin et.al elaborated further:

> Statistical literacy is essential in our personal lives as consumers, citizens, and professionals. Statistics plays a role in our health and happiness. Sound statistical reasoning skills take a long time to develop. They cannot be honed to the level needed in the modern world through one high-school course. The surest way to help students attain the necessary skill level is to begin the statistics education process in the elementary grades and keep strengthening and expanding students' statistical thinking skills throughout the middle- and high-school years. A statistically literate high-school graduate will know how to interpret the data in the morning newspaper and will ask the right questions about statistical claims. He or she will be comfortable handling quantitative decisions that come up on the job, and will be able to make informed decisions about quality-of-life issues. (p. 3)

Finally, an examination of statistical literacy is important because pre-service elementary teachers need to be able to function independently on a daily basis in their own lives regarding information to which they are exposed. However, pre-service teachers may not be sufficiently statistically literate for this to occur. Pierce and Chick (2012) asserted that teachers are expected to interpret and administer complex data about school and student performance, but may not have the necessary knowledge to do so. In their study involving pre-service elementary teachers, Chick and Pierce (2008) concluded that more work needs to be done to help pre-service elementary teachers develop statistical knowledge to identify important statistical concepts involving real world data. They also claimed that statistical teaching depends on how the teacher perceives and understands statistical knowledge. Lee, Kersaint, Harper, Driskell, and Leatham (2012) emphasized that teachers need a deeper statistical knowledge base in order to engage in worthwhile statistical problem solving, for themselves and their students. Pre-service teachers also need to be statistically literate because statistical literacy is vital not only for society in general, but also for individual citizens, as they are required to make informed decisions based on information and data analysis that are provided by other members of the community (Watson & Callingham, 2003) . So, although statistical literacy plays an important role in the lives of pre-service teachers, many are not statistically literate.

Furthermore, policy makers in education are also aware of the need for pre-service teachers to be statistically literate. According to Sorto (2004), a complete examination of national and state standards regarding statistical knowledge revealed that future teachers must understand and be able to teach specific content areas, including data representation and measures of center. Thus, if teachers are going to meet the standards defined by their respective departments of education, they must be statistically literate.

Technology in Mathematics and Statistics Education

Technology can be defined as a practical application of particular knowledge or using technical skills to accomplish a task (Webster, 2006). It can also be defined as scientific applications used in industry and commerce or digital and electronic systems and products

(Mifflin, 2000). It is most beneficial in this study to focus on the second definition given by the American Heritage Dictionary regarding digital products and systems. The discussion begins by exploring the effect of technology on education, and then narrows by focusing on the effect of computer software on education, since the research questions of this study deal specifically with computer software.

Educators have long used tools and technologies to aid in the learning process. These technologies have been very useful to both teachers and learners in exploring new ideas and concepts. However, technology as defined earlier has only recently become a part of the educational landscape. As each new technology is developed, educators recognize the value of that technology and debate how to apply it for educational purposes (Jonassen, Peck, & Wilson, 1999). Educators understand that technology can provide valuable and adaptable media for representation of student learning. The debate is over *how* to use the technology to foster learning. The authors explained that a large amount of computer technology research shows that computers are no more effective than teachers at teaching students. However, if we consider technologies as educational tools that students learn *with*, rather than *from*, then the basic core of student learning changes. These learning changes are explained in *Partners in Learning: Twelve Ways Technology Changes the Teacher-Student Relationship* (McGrath, 1998). McGrath reported on key themes that emerged via discussions with teachers regarding students learning with technology in the classroom. Technology increases student motivation which is likely to increase student learning. Collaboration and cooperation are promoted when using technology as a learning tool. Computers in a classroom setting enable conversations to become more probing and have more depth. Teachers can become facilitators to learning by using technology. There is a balance of power enjoyed by both teacher and student. Students are more persistent solving problems when using technological tools. Technology enables multiple methods of assessment. A classroom with computers can encourage teachers to work successfully with diverse students. The use of technology in class can improve communication, both oral and written. Technology can provide opportunities for understanding to be deepened. Teachers are more able to employ interdisciplinary connections using technological tools. Technology adds relevance to classroom activities and students are more engaged as a result.

The arrival of microcomputers in the 1980s changed the world, and with it education. The personal computer is arguably the single most important technological discovery of the last century, and at the very least, *one* of the most important technological discoveries. Weizenbaum (1976) suggested that the advent of the computer threatened the stability of the world. He was commenting on the fact that the arrival of the computer opened new doors to discovery, like outer space, but closed certain doors that were once open, some irreversibly, such as many occupations brought about by the industrial revolution. These occupations could be eliminated altogether or changed so dramatically by technology, that workers would no longer be required. He stated that the computer is not merely a device, but an agent of change and affirms that computers are powerful, new metaphors that can help us understand our world. As the computer has become more integrated into society, the greater our dependence on them. "Our society's growing reliance on computer systems that were initially intended to 'help' people make analyses and decisions, but which have long since both surpassed the understanding of their users and become indispensable to them, is a very serious development" (1976, p. 236).

Although *Computer Power and Human Reason* was written over 30 years ago, Weizenbaum's analysis of the relationship between computers and society, including education, is accurate. Seymour Papert (1980) continued this line of reasoning regarding computers acting as agents of change, specifically as it pertains to education. In *Mindstorms*, he explained that his research was shaped by two main themes—that children can and do master learning with a computer, and that their computer knowledge will change how they learn everything else. Although he wrote *Mindstorms* over 25 years ago, his analysis of the computer's role in education is still relevant. Consider the two fundamental ideas that run through his book--"it is possible to design computers so that learning to communicate with them can be a natural process" and "learning to communicate with a computer may change the way other learning takes place" (1980, p. 6). This perspective is reinforced by Masalski (2005) in *Technology-Supported Mathematics Learning Environments*, the sixty-seventh yearbook of NCTM, where each chapter describes the educational use of a particular technology in teaching and learning mathematics. Canton (1999) is also in agreement with this point of as demonstrated by his claim that computers are powerful extensions of humans that are designed for augmenting intelligence, learning, and communication. Papert proceeded to explain how students used the LOGO environment on the computer to learn new concepts and also learn new ways of learning and thinking. The vision he presented is one that is a culture of computers that can help us learn and understand how to learn.

One common theme evident in this discussion is working *with* the computer to acquire knowledge and learning how to acquire knowledge. This idea of interactivity is echoed by de Freitas, Oliver, Mee, & Mayes (2008) when they emphasized the importance of having support for the learner to be engaged with the tool, in this case a computer. This idea is also reinforced by Friesen and Feenberg (2007) when discussing educational technology and cognitive processes. The learner and the software are considered as a single cognitive system working together to solve problems. Along with interactivity, learner freedom is very important. If students are not allowed to explore their own pathways to learning concepts, then they may at times be hindered in their cognitive growth. Biehler (1993) made this point when emphasizing the need for flexible learning environments that support the learner's new freedom. This is supported by Twining (2002) who claimed that many valuable educational experiences involving a computer are not planned. They arise from the genuine educational needs of students and computers are able to meet those needs.

Computers are powerful tools for learning and teaching, particularly when coupled with dynamic interactive software that enhances learning and teaching. When studying the modeling of mechanical linkages using interactive geometry software, Vincent (2005) reached the following conclusion. “Although the tactile experience and satisfaction of working with real (mechanical) and geostrip linkages represented a significant motivational aspect, the students recognized that the computer models offered them more useful empirical feedback. Their trust in the interactive geometry data strengthened their confidence in their conjectures and encouraged them to seed geometric explanations” (2005, p. 110). Knuth and Hartmann (2005) reported on the enhancement of learning via computer software by exploring three different problems that are modeled using an interactive geometry software program. The three problems involve a system of equations, a line of best fit, and the behavior of the sine function. The examples illustrate how this technology is used to fortify the efforts of teachers to foster the understanding and intuition of students by engaging them in conceptual conversations. They conclude that the illustrations are intended to exemplify the different ways that technology can help foster student understanding of the mathematics they are studying. When discussing the effect of using dynamic data analysis software on learning about statistics, Bakker and Frederickson (2005) concluded that the experience was rewarding for the students because they were quite motivated to use it. It also offered the opportunity to investigate different representations in search of a significant and meaningful plot which they could use to answer the question at hand. Thus, students were able to analyze very large data sets that would have been difficult to analyze by hand. Furthermore, they could calculate means and other measures rather quickly. Thus, if dynamic statistical software is used as a learning tool that students can learn *with*, not necessarily from, then the potential exists for an enhancement and improvement of their statistical learning experience.

Effective Use of Technology in Mathematics and Statistics Education

As new software and hardware are being developed at an increasing rate with each passing year, mathematics and statistics educators are looking for the technological tools that would accentuate their students' learning experience. When evaluating statistical software, Rolf Biehler (1997) identified three basic problems: the complexity of tool problem, the closed microworld problem, and the variety problem. The complexity of tool problem deals with the concerns that professional statistical systems are quite complex and require a high level of cognition at the beginning. Often they are not designed for novices who need a bottom-up perspective. The closed microworld problem refers to constraints that are intended to enable students to concentrate on the central aspects of a learning situation. The variety problem deals with the need for educators to use different statistic programs to accomplish different goals and none of the programs are compatible with each other.

Four important criteria to consider when evaluating statistical software are highlighted by Biehler (1997). First, students should be able to analyze data using an exploratory style. They need to be empowered to complete some small scale data analysis work that reflects the interactive and exploratory nature of real data analysis in practice. Second, students can actively participate by taking on the role of statistics researcher. Third, students must be enabled to construct models for experiments and use computer simulation for study. Fourth, the software should help fortify the exploration of various new ideas in teaching content.

Any discussion of an appropriate use of technology for statistical learning should include a mention of the TPACK (Technological Pedagogical Content Knowledge) framework. While it is beyond the scope of this study to investigate the influence of TPACK on statistical learning, there are elements of the TPACK framework that are germane to this discussion. TPACK is an extension of the idea of pedagogical content knowledge championed by Lee Shulman (1986). Mishra and Koehler (2008) explained that in the TPACK framework, understanding is developed via interactions among, technological, pedagogical, and content knowledge. They continued, "It is the interactions, between and among these components, playing out differently across diverse contexts, that account for the wide variations seen in educational technology integration" (Mishra and Koehler, 2008, p.3). While admitting that there is no singular *best* way to integrate technology and curriculum, Koehler and Mishra (2009) asserted that efforts to integrate technology into the curriculum should be creative and designed for specific subject matter in particular environmental contexts. This statement reflects the core of the TPACK framework. Whether the technology is designed for educational purposes or not, Mishra and Koehler (2009) argued that teachers must be willing to experiment with technology and to develop an openness to creating new experiences for their students in order for new technological tools to become truly educational.

In *Learning with Technology* (1999), Jonassen, Peck, and Wilson discussed some useful roles for technology in learning. These roles include a tool to support knowledge construction, a context that supports learning-by-doing, a social medium that supports learning via conversing, and an intellectual partner supporting reflection and learning. The authors then discussed how these roles are played out by various technologies including the internet, video, hypermedia, and learning communities.

This fact is highlighted again by Laurillard (2002) in *Rethinking University Teaching*. Laurillard stated that each subject in academia faces that same challenge, to aid students in expanding their experiential boundaries, changing their perspective and altering their interaction with the world. She then proceeded to discuss how this challenge is met via technologies like hypermedia, educational games, and virtual worlds, which are dependent on the personal computer.

Petocz and Reid concluded, “Students learn statistics only if they actually practice statistics through a whole range of statistical activity supported by an appropriate computer package and discussion” (2001, p. 69). Chance and Rossman (2006) echoed this opinion and state that computer software can be used to directly involve students in data analysis and that technology can be a very effective tool for instruction. Basturk (2005) agreed. “To be more effective, using computers with software programs in the introductory statistics course would be one of the important ways to improve student knowledge about statistics and its usefulness in real life.” (p. 175) Garfield, Chance, and Snell (2002) concurred with this idea as well, saying that teachers are encouraged to use technology not just in numerical computation, but also to explore and enhance student learning. Technological tools have led to numerous changes in statistics. Problems that were fractious before now have solutions. Assumptions made to simplify models no longer need to be made. These changes directly influence the statistics content that should be taught. Chance, Ben-Zvi, Garfield, and Medina (2007) concluded that technology plays a major role in the improvement of student learning of statistics. This opinion is seconded by Mills (2004) who claimed, "Technology is a powerful medium that can provide efficient methods for delivering instructional objectives to students. It is gaining acceptance worldwide in academia and empirical research will be important to document the effect of these new learning tools on student achievement" (p. 26).

Tinkerplots and Statistical Learning

The benefits of a dynamic statistical software program have been examined by numerous mathematics educators. Lane-Getaz (2006) extolled the use of dynamic statistical software by teachers to incorporate conceptual models into their teaching which helps students develop statistical thinking. Franklin and Garfield (2006) included the employment of software for teaching statistics as one of their recommendations for developing statistical thinking. Rubin and Hammerman (2006) echoed this recommendation explaining that data visualization software can promote deeper explorations of data by enabling teachers and students to create diverse representations that can propagate different kinds of questions and arguments.

When discussing the effect of using dynamic data analysis software on learning, Lane & Tang (2000) explained that computer simulations can play a significant role in improving students' ability to study statistical concepts. In discussing the synergy of content, pedagogy and technology, Moore (1997) reinforced the importance of computers in learning statistics when he says "computer-assisted learning may at last enable genuinely active learning on a technological platform" (p. 130). When studying *Tinkerplots™* effect on the development of students' understanding of statistics, Watson and Donne (2009) explained that results are promising. When considering the use of technology, specifically statistical software, in today's world, they stated that the services offered by *Tinkerplots™* are valuable to both the classroom teacher, who is developing statistical literacy and the researcher, who is evaluating the development. After studying the use of *Tinkerplots™,* a dynamic statistics computer program, in a classroom setting, Rubin and Hammerman (2006) concluded that "visualization software is a particularly powerful way to highlight and explore (statistical) concepts" (p. 254). Although dynamic statistical software is being utilized and studied in the classroom, research on the success of the program in the classroom is still relatively sparse. Thus, this study is motivated by a need to determine if dynamic statistics computer programs are effective in improving students' statistical literacy.

Bakker and Frederickson (2005) referred to *Tinkerplots™* as a bottom-up educational tool for building graphs of data. While the program is quite capable to analyzing and displaying data, it is more. Keller (2005) claimed that it is a customizable, student-driven program that "takes students to a higher level of critical thinking as it helps them see trends and patterns in data, and then shows them how to use that data to make graphs representing their findings" (p. 11). The software comes with numerous ready-to-analyze data sets that include a variety of topics. Students can experiment by importing and exploring any of these data sets. This exploration can include sorting data values by attribute, creating tables, drawing graphs, and adding data values to see what changes will occur. Although this is a valuable asset of the program, the most beneficial part and meaningful use for *Tinkerplots™* is the capability that students have to build their own data sets, which they can then analyze. These freedoms to create rich data sets, pose original problems, and construct & manipulate data graphs are highly valued by mathematics educators. "The mathematical activity possible with *Tinkerplots™* in the background is rich in dialogue and focuses on reasoning with and about data" (Steinke, 2005, p. 11) Tools like *Tinkerplots™* can aid students in understanding the *why* behind statistical concepts. According to Cleveland (1993), having the ability to display data in flexible and multiple ways leads to interesting insights, thoughts, and ideas, which can then be modeled more formally.

Tinkerplots™ enables students and teachers to do things that they were previously unable to do in the classroom because of time or size constraints or curriculum limitations. This program was developed to cause students to think beyond the pages of the book. Students are able to predict, collaborate, critically think, analyze, and solve problems, all by observing patterns from series of dots. Math educators can utilize this technology to explore and analyze data with their students in a smooth an efficient manner, something they may have been unable to do before. "With this bottom-up tool for constructing graphs, students can explore data sets with multiple representations, both unconventional and conventional, in ways that are not feasible by hand" (Bakker & Frederickson, 2005, p. 79). The use of *Tinkerplots™* is also rewarding for the student in several ways. First, they are motivated. Second, they can represent data sets in multiple and meaningful ways. Third, they can analyze data sets whose size would previously inhibit analysis by hand. Fourth, they can quickly produce calculations for measures of central tendency. Thus, based on previous research, *Tinkerplots™* shows promise as an educational tool and satisfies the criteria for educationally sound statistical software as highlighted previously by Biehler (1997).

Summary

It is clear that pre-service elementary teachers not only must possess an adequate level of mathematics content knowledge, but also be statistically literate. It is also clear that computer technology, when used properly, can be a powerful tool for learning mathematics and statistics. *Tinkerplots™* is one example of technology that, when used appropriately, can enhance statistical learning. After studying the use of *Tinkerplots™* in a classroom setting, Rubin and

Hammerman (2006) concluded that "visualization software is a particularly powerful way to highlight and explore [statistical] concepts" (p. 254). Although dynamic statistical software like *Tinkerplots*™ is being utilized and studied in the classroom, research on the program's influence on learning is still relatively exiguous. Furthermore, there is very little research on the statistical literacy of pre-service elementary teachers. This is remarkable, considering the importance of statistical literacy for these teachers and the vital role they play in the educational growth of their students. Thus, there is a considerable shortage of research regarding statistical software programs' influence on the statistical understanding of pre-service elementary teachers. In order to help address this research deficit, this study was conducted to determine if *Tinkerplots*™ influences pre-service elementary teachers' statistical literacy by investigating their understanding of graphical representations and measures of center.

CHAPTER THREE

METHODOLOGY

The purpose of this study was to determine if the use of *Tinkerplots*™ in a college mathematics classroom significantly improves pre-service elementary teachers' level of understanding of graphical representations of data and measures of center. Quantitative data were collected and analyzed to determine the pre-post level of pre-service elementary teachers' understanding of graphical representations of data and measures of center. Qualitative data were collected and analyzed to augment the interpretation of the pre-service elementary teachers' understanding of graphical representations of data and measures of center. In this chapter, the method and procedures used to collect and analyze the data are described and the research design is addressed.

The research questions guiding this study were:

1. How does the use of *Tinkerplots*™ influence preservice elementary teachers' understanding of graphical representations of data (i.e. selection, use, and ability to make inference)?
2. How does the use of *Tinkerplots*™ influence preservice elementary teachers' understanding of measures of center (i.e. selection, use, and ability to make inference)?

Research Design

While there is a large body of research that incorporates the combination of both quantitative and qualitative data, the debate regarding the use of mixed methods continues.

According to Creswell (2003), the opinion from purists in either realm of methodology is that quantitative and qualitative methods should never be mixed. However, Creswell described the advantages of a mixed methods design by stating that the use of both approaches in tandem improves the overall robustness of the study more than qualitative or quantitative research alone. He presented several mixed method strategies, including sequential, concurrent, and transformative. This study used the concurrent strategy which allows the researcher to collect qualitative and quantitative data simultaneously. Creswell described three different approaches to a concurrent strategy: concurrent triangulation, concurrent embedded and concurrent transformative. The approach used for this study was the concurrent embedded strategy. According to Creswell (2009), a "concurrent embedded approach has a primary method that guides the project and a secondary database that provides a supporting role in the procedures" (p. 213) Using the concurrent embedded strategy, this study was driven by the quantitative data analysis and supported by the qualitative data analysis. Thus, both qualitative and quantitative data were used for the purpose of expansion in order to add scope and breadth to the study.

Participants

The subjects of this study were drawn from a population of elementary education pre-service teachers at a Midwestern regional university. Participants were enrolled in one of two sections of a mathematics modeling course, with one section being randomly selected as the control group and the other being selected as the experimental group in a quasi-experimental design. Through purposive sampling, a total of thirty-four elementary education pre-service teachers participated in this study. Thirteen participants were in the control group and twenty-one participants in the experimental group.

Demographic information including gender, age, academic classification, marital status, and race were collected via surveys. Survey results are summarized in Table 1.

Table 1

Demographic Data

Characteristic	Experimental N (%)	Control N (%)
Gender		
Male	2 (5.9)	2 (5.9)
Female	18 (52.9)	12 (35.3)
Age Group		
18-21	8 (23.5)	6 (17.7)
22-25	6 (17.7)	3 (8.8)
26-30	3 (8.8)	3 (8.8)
31 and older	3 (8.8)	2 (5.9)
Academic Class		
Sophomore	5 (14.7)	4 (11.8)
Junior	10 (29.4)	4 (11.8)
Senior/Graduate	5 (14.7)	6 (17.7)
Marital Status		
Single	12 (35.3)	9 (26.5)
Married	5 (14.7)	4 (11.8)
Divorced	3 (8.8)	1 (2.9)
Ethnicity		
White	11 (32.4)	9 (26.4)
African American	0 (0)	0 (0)
Hispanic	0 (0)	0 (0)
Asian	0 (0)	0 (0)
Native American	7 (20.6)	7 (20.6)

Three interview participants were randomly selected from the experimental group. The interviews were video recorded. All participants signed a consent form before participating in any data collection.   Interview participants signed an additional consent form before participating in any video recording.

Setting

Participants in the two different course sections met two days during the week for the same amount of time each day and had the same instructor for the course. The six week data analysis module was identical for both groups. The only difference was in the experimental group's use of *Tinkerplots*™ during the experimental timeframe. The timeline for the module is included in Table 2.

Table 2

Timeline for Experimental Statistics Module

Week	**Activity**	**Description of Activity**
1	Pre-Assessments Pre-Questionnaires Concept Maps Demographic Data	Participants completed Assessments, Questionnaires, Concept Maps, and Demographic Surveys
2	Introduction to Graphs	Participants were introduced to different visual representations of data and asked to create and analyze graphs.
3	Fish Activity	Participants were required to compare to different sets of data, normal fish and genetically altered fish, using visual displays.
4	Yo-Yo Activity	Participants were asked to determine the most likely time for a break-in based on analyses of different visual displays of data.
5	Backpack Activity	Participants determine if elementary students are carrying backpacks that are too heavy based on analysis of stacked bar charts.
6	Post-Assessments Post-Questionnaires Concept Maps Interviews	Participants completed Assessments, Questionnaires, Concept Maps, and Interviews

All participants were enrolled in one of two sections of the same mathematics modeling course which were taught by the same instructor, and on the same schedule, at a Midwestern regional university. A more detailed description of the mathematics modeling course can be found by reading the course syllabus (See Appendix I). During the experimental timeframe, participants in the control group completed learning activities by working in groups at tables during class time in the Mathematics Modeling classroom on campus. Participants in the experimental group completed learning activities by working in groups during class time at computer stations and using *Tinkerplots*™ in the computer lab on campus. The learning activities (See Appendix I) consisted of problem sets that reflected the focus of the research questions. Each activity was completed in two sessions.

The activities that participants completed were chosen specifically because of how they reflected the research questions of this study. Students were given a set of data which they then had to graph, analyze, and use to predict outcomes and answer questions regarding the data set in question. To accomplish this, the participants depended on their own understanding of graphical representations, measures of center, and how to make informal inferences about the data. The control group completed the activities using only paper and pencil methods. The experimental group was given an orientation to the *Tinkerplots*™ program during the first class period in the computer lab prior to the Introduction to Graphs activity. At the conclusion of the orientation, participants in the experimental group were able to complete the activities using *Tinkerplots*™ for the entire experimental time frame.

Instrumentation

A variety of data were collected in order to explore the influence of *Tinkerplots*™. Data included a Statistical Assessment, Statistics Questionnaire, semi-structured interviews and concept maps. Each of these instruments is described in this section.

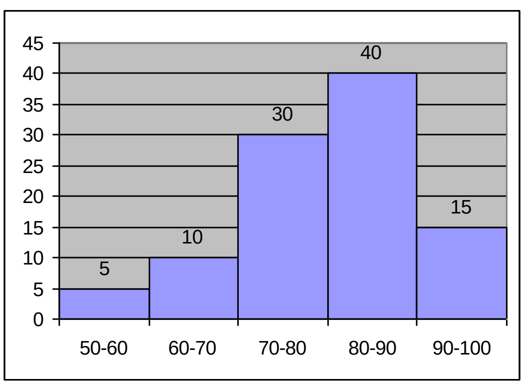
Statistical Assessment

The Statistical Assessment (SA) consisted of eleven items (see Appendix A) that dealt with graphical representations and measures of center. A sample item from the Statistical Assessment is provided in Figure 2. The questions on the Statistical Assessment were designed to specifically address one or more part of each research question (see Table 3).

Table 3

Organization of Assessment Questions Regarding Research Question Being Addressed

	SELECTION	USE	INFERENCE
MEASURES OF CENTER	Q#1, Q#2,	Q#1, Q#3, Q #4	Q#1 Q #7
GRAPHICAL REPRESENTATIONS	Q#5, Q#7	Q#3, Q#4, Q#6, Q#9, Q#10	Q#8Q#11



The manager of the local BOWL-MORE was interested in the distribution of bowling scores for first-time bowlers. He collected information from the past year and constructed the histogram below. Using this graph, what was the approximate median score for this group of first-time bowlers?

Explain your reasoning.

Figure 2. Sample item from Statistical Assessment

Participants were asked to explain his/her reasoning regarding their choice on items one through five as well as items seven and eight. The assessment took approximately 30 minutes to complete. Responses on all eleven items were scored by two researchers using one of two rubrics depending on the type of question. Those items that involved an explanation (items one through five, seven and eight) were scored using three criteria: explanation, demonstrated knowledge, and requirements (see Table 4). Each criterion was scored on a five-point scale (0-4), thus each response for items requiring an explanation could receive a score ranging from 0 to 12. Items that did not involve an explanation (items six and nine through eleven) were scored using two criteria: demonstrated knowledge and requirements (see Table 5). Each criterion was scored on a three-point scale (0-2); therefore each response could receive a score ranging from 0 to 4. Possible cumulative scores on the assessments ranged from 0 to 100.

Table 4

Rubric A Evaluates Q1-Q5 and Q7-Q8 on Pre-and Post-Statistics Assessments

SCORE	**4**	**3**	**2**	**1**	**0**
Explanation	A complete response with a detailed explanation	Good solid response with clear explanation	Explanation is unclear	Poor explanation/ Misses key points	No explanation
Demonstrated Knowledge	No errors of any kind	No major errors or serious flaws in reasoning	May be some errors or flaws in reasoning	Some errors or flaws in reasoning	Major errors or serious flaws in reasoning
Requirements	Goes beyond the requirements of the problem	Meets the requirements of the problem	Almost meets the requirements of the problem	Hardly meets the requirements of the problem	Does not meet the requirements of the problem

The Statistics Assessment (SA) was checked for both internal reliability and face validity. The Cronbach's alpha reliability coefficient for the pre-service teachers' SA scores was 0.714. According to Nunnaly (1978), this reflects an acceptable internal reliability. The reliability coefficient for teachers' SA scores on the measures of center and graphical representations subscales were 0.686 and 0.682 respectively.

Table 5

Rubric B Evaluates Q6 and Q9-Q11 on Pre-and Post-Statistics Assessments

SCORE	**2**	**1**	**0**
Demonstrated Knowledge	No errors/correct answer	Major errors/incorrect solution	No solution
Requirements	Goes beyond the requirements of the problem	Meets the requirements of the problem	Does not meet requirements of problem

In order to determine the face validity of this instrument, an expert panel consisting of mathematics and mathematics education faculty were invited to review the instrument. The assessment was sent to the members of the panel and feedback was collected by the researcher. The panel reviewed the instrument and determined that the questions would yield data commensurate with the research questions for this study.

Concept Maps

A concept map is a two-dimensional drawing that is used to represent relationships among a student's concepts related to a central idea or topic. Individual thoughts, ideas or concepts on the map are represented by labeled boxes or circles that are joined by lines that represent a link or connectedness in the respondent's mind between the concepts. The student builds his or her map around a central idea or topic and new topics are adjoined in a hierarchical network. (Hough, O'Rode, Terman, & Weissglass, 2007) At first glance, concept maps may appear to just be a pictorial representation of information. However, Novak and Canas (2008) stated that when one understands the foundations for concept maps, one begins to see it as a powerful learning tool with profound meanings. Furthermore, they claimed, "Concept mapping has been shown to help learners learn, researchers create new knowledge, administrators to better structure and manage organizations, writers to write, and evaluators assess learning" (2008, p. 29).

Each participant in the study completed a concept map during a class period at the beginning of the data analysis module in the mathematics modeling course and again at the end of the data analysis module. Participants were instructed to create a concept map on a piece of paper beginning with the word "statistics" in the center. This was the center "node". Participants then linked other concepts, or nodes, to the center node by drawing lines between them. They continued linking statistical concepts until no further concepts, or nodes, could be identified. The concept maps were used to address the first research question regarding participant general statistical knowledge.

Concept maps were scored using Table 6. The number of concepts, the width, the length, the HSS, and the number of chunks were recorded for each participant on the pre-treatment concept maps and the post-treatment concept maps. A supplementary analysis of the concept maps was conducted using a software program called *Wordle* (Feinberg, 2009) that generates word clouds. According to McNaught and Lam (2010), word clouds report the frequency of the different words that occur in a portion of text and can illuminate viewers to main themes or ideas that are maintained by the author of the text. Thus, *Wordle* was used to analyze the text in the concept maps to provide more information that may help answer the research questions.

Table 6

RUBRIC C Evaluates Concept Maps

TERM	DEFINITION	COMMENT
Concept Number	Total number of concepts on each map	The number of concepts on a map is assessing the amount of statistics terms that a person knows.
Width	Greatest number of concepts at one particular level on the map; the widest point on the map	The width captures the breadth of knowledge.
Depth	Length of the longest chain on the map	The depth reflects the depth of a person's knowledge.
HSS (Hierarchical Structure Score)	Width + Depth	HSS assesses the complexity of the map structure.
Chunk Number	Total number of chunks on each map, where a chunk is defined by any node that is linked by two or more concepts	Assesses the extent to which concepts and thoughts are interconnected, demonstrating connectivity of the structure of mathematical understanding
Crosslink Number	The total number of crosslinks on each map where a crosslink is defined as a link between two chunks.	

Note. From Using concept maps to assess change in teachers' understandings of algebra: A respectful approach (Hough, O'Rode, Terman, & Weissglass, 2007)

Questionnaires

The pre-questionnaire (See Appendix B) consisted of two open-ended questions dealing with participant understanding of measures of center and graphical displays of data, respectively, as well as five more questions where participants rated their own understanding of measures of center, graphical representations of data, and informal inference. Participants were asked to explain their reasoning for each rating on these five questions.

There were two post-questionnaires, one for the control group (See Appendix C) and one for the experimental group (See Appendix D). Both the control group and the experimental group answered the same open-ended questions as on the pre-questionnaire and two additional open-ended questions dealing with the impact of the learning experiences on participants' ability to analyze and interpret data and represent data graphically. Additionally, the experimental post-questionnaire included ten items where participants, using a five-point Likert-type scale (5 = "strongly agree" to 1 = "strongly disagree") rated their overall experience with *Tinkerplots*™. The questionnaires took approximately twenty minutes to complete.

In order to determine the face validity of these instruments, an expert panel consisting of mathematics and mathematics education faculty were invited to review the instruments. The questionnaires were sent to the members of the panel and their feedback was collected by the researcher. The panel reviewed the instruments and determined that the questions would yield data commensurate with the research questions for this study.

Semi-Structured Interviews

Semi-structured interviews were conducted with a small random sample (N = 3) of the pre-service elementary teachers from the experimental group. Participants were assigned numbers and those numbers were then drawn from a container to determine the random sample.

The pre-service elementary teachers selected to complete the interview answered questions designed to examine their experience with *Tinkerplots*™ and its potential influence on graphical representations of data, measures of center, and general statistical knowledge.

The interview protocol (Appendix E) focused on selected questions delving into the effect of *Tinkerplots*™ on both understanding of graphical representations of data and measures of center. Although conversations were guided by the interview protocol, the design was continuous and flexible. Questions were sometimes modified to probe for more meaningful information as interviews progressed. Interview questions included:

- "Tell me about your experiences studying statistics prior to taking this course."
- "How did the use of *Tinkerplots*™ influence your general statistical knowledge?"
- "How did the use of *Tinkerplots*™ influence your understanding of measures of center?"

Interviews were video recorded and transcribed by the researcher for subsequent interpretation and analysis.

Procedure

Each participant in the study (N = 34) completed the Statistics Assessment during a class period at the beginning of the data analysis module in the mathematics modeling course. The Statistical Assessment instruments were distributed by the investigator to each participant at the beginning of the class period and collected by the investigator at the end of the class period. Participants spent six weeks completing the data analysis module in the mathematics modeling course (see Table 2). After completion of the module, participants in the both the control and experimental sections were given the Statistical Assessment again. Assessments were again distributed by the investigator to each participant at the beginning of the class period and collected at the end of the treatment.

Each participant in the study completed a concept map during a class period at the beginning and at the end of the data analysis module in the mathematics modeling course. Both pre-treatment and post-treatment concept maps were described by the investigator to the participants at the beginning of the class and collected from the participants by the investigator at the end of the class period.

Participants in both the control group ($N = 14$) and the experimental group ($N = 20$) completed both a pre- and a post-questionnaire. Pre-questionnaires were distributed and collected by the investigator during the class period at the beginning of the data analysis module and post-questionnaires at the end of the data analysis module.

Interviews were conducted with a random sample ($N = 3$) of the pre-service elementary teachers participating in the experimental group. The pre-service teachers selected to complete the interview answered questions designed to examine their experience with *Tinkerplots™* and its potential effect on understanding of measures of center, graphical representations of data, and general statistics knowledge. Interviews were conducted at the conclusion of the data analysis module. The researcher video recorded the interviews in his office on campus and transcribed the interviews for subsequent analysis.

Data Analysis

Quantitative data were collected using the pre-post Statistical Assessments, pre-post Statistics Questionnaires, pre-post concept maps, and post *Tinkerplots™* surveys. The data were analyzed using SPSS (version 18.0) software to determine the level of understanding of pre-service elementary teachers regarding graphical representations and measures of center. Data from the concept maps were analyzed using *Wordle* (Feinberg, 2009), which was used to generate word clouds (See Appendix K) from the concept maps of participants in both groups.

Word clouds were analyzed qualitatively to help determine if there was a difference between the control and experimental groups.

Qualitative data were collected from the Statistical Assessments, Statistics Questionnaires, concept maps, and interviews. The data were analyzed to cultivate a deeper meaning regarding pre-service elementary teachers' understanding of measures of center and graphical representations of data. The questionnaire responses and transcribed interviews were interpreted by the researcher using the constant comparative method (Boeije, 2002; Glaser, 1965). The constant comparative method enabled the researcher to break down the data into discrete pieces or *incidents*, and then code them into categories. Throughout the analytical process, the categories are then refined and developed as new pieces of data, or incidents, are compared and categorized.

Research Question 1: How does the use of *Tinkerplots*™ influence preservice elementary teachers' understanding of graphical representations of data (i.e., selection, use, and ability to make inference)?

In order to answer the first research question related to pre-service elementary teachers' understanding of graphical representations of data, quantitative data were examined using the questions on the Statistical Assessment pertaining to graphical representations (see Table 3). Scores on post- Statistical Assessment from both the control and experimental groups were compared to determine if *Tinkerplots*™ had a significant effect on the participants' understanding of graphical representations during the experimental timeframe. Because the number of participants in each group was small ($N < 30$), an independent samples Mann-Whitney U test was conducted on the pre- Statistical Assessment scores to show there was no significant difference in the groups at the pre-test level. Since groups were randomly assigned, post-Statistical Assessment scores were compared using an independent samples Mann-Whitney *U* test to determine if there existed a significant difference between the two groups. Qualitative data regarding pre-service elementary teachers' understanding of graphical representations of data were examined using the questionnaires, concept maps, and interviews.

Research Question 2: How does the use of *Tinkerplots*™ influence preservice elementary teachers' understanding measures of center (i.e., selection, use, and ability to make inference)?

In order to answer the second research question related to pre-service elementary teachers' understanding of measures of center, quantitative data were examined using the questions on the Statistical Assessment pertaining to measures of center (see Table 3). Scores on post- Statistical Assessment from both the control and experimental groups were compared to determine if *Tinkerplots*™ had a significant effect on the participants' understanding of measures of center during the experimental timeframe. Because the number of participants in each group was small ($N < 30$), an independent samples Mann-Whitney *U* test was conducted on the pre-Statistical Assessment scores to show there was no significant difference in the groups at the pre-test level. Since groups were randomly assigned, post-Statistical Assessment scores were compared using an independent samples Mann-Whitney *U* test to determine if there existed a significant difference between the two groups. Qualitative data regarding pre-service elementary teachers' understanding of measures of center were examined using the questionnaires, concept maps, and interviews.

Ethical Considerations

The privacy and confidentiality of the subjects were protected through the use of pseudonyms for all participants. An assurance of privacy and confidentiality was presented in writing to each participant. Since the participants are all students, they were assured that their participation in the study would in no way affect their grade or performance in the course. The research participants were also given the opportunity to withdraw from the study at any time as outlined in the approved IRB.

Summary

The purpose of this study was to determine if the use of *Tinkerplots*™ in a college mathematics classroom influenced pre-service elementary teachers' level of understanding of graphical representations and measures of center. Using a quasi-experimental quantitative framework, data were collected using the Statistical Assessment, Statistics Questionnaires, concept maps, and *Tinkerplots*™ surveys. Using qualitative techniques, data were collected using the Statistics Questionnaires and concept maps. Also, qualitative data were collected through an interview process conducted on a subset of the pre-service elementary teachers. The data were analyzed using both quantitative and qualitative techniques. Results of data analysis are reported and explored in the next chapter.

CHAPTER FOUR

RESULTS

This mixed methods study investigated quantitative and qualitative data for the purpose of determining the influence of *Tinkerplots*™ on pre-service elementary teachers' understanding of graphical representations of data and measures of center. Using a concurrent embedded strategy (Cresswell, 2008) the researcher meshed both quantitative data and qualitative data to render a more complete analysis of the issue being researched. Using a purposive sample, quantitative data were collected and analyzed to determine pre-service teachers' understanding of graphical representations of data and measures of center. Additionally, qualitative data were collected and analyzed to develop a deeper understanding of the pre-service teachers' statistical knowledge.

The research questions guiding this study were:

1. How does the use of *Tinkerplots*™ influence preservice elementary teachers' understanding of graphical representations of data (i.e. selection, use, and ability to make inference)?
2. How does the use of *Tinkerplots*™ influence preservice elementary teachers' understanding of measures of center (i.e. selection, use, and ability to make inference)?

The following sections in this chapter address pre-treatment analysis prior to instruction, analysis of the influence of the use of *Tinkerplots*™ on pre-service teachers' understanding of graphical representations and understanding of measures of center, and concluding remarks.

Pre-Treatment Analyses

The number of participants in each group was small ($N < 30$), therefore an independent samples Mann-Whitney U test was conducted for quantitative analyses. Using the pre-Statistical Assessment scores, an independent samples Mann-Whitney U test was conducted to determine if there was any significant difference between the experimental group and control group at the beginning of the experimental time frame. Analysis revealed no significant difference found between the two groups, $U = 120.0$, $p > 0.05$, with the sum of ranks equal to 370 for the experimental group and 225 for the control group. Since the Statistical Assessment was broken into two subscales, measures of center and graphical representations of data, an independent samples Mann-Whitney U test was also conducted to determine if there was any significant difference between the two groups in relation to the two subscales. Analysis revealed no significant differences between the two groups, $U = 128.5$, $p > 0.05$, on the measures of center subscale with the sum of ranks equal to 361.5 for the experimental group and 233.5 for the control group. Additionally, analysis revealed no significant differences found between the two groups, $U = 132$, $p > 0.05$, on the graphical representations subscale with the sum of ranks equal to 358 for the experimental group and 237 for the control group (see Table 7).

Pre-Service Elementary Teachers' Understanding of Graphical Representations

In order to examine pre-service elementary teachers' understanding of graphical representations, the Statistical Assessments and Questionnaires consisted of items that dealt with participants' understanding of how to appropriately select graphs, correctly use graphs, and apply informal inference with graphs. Quantitative data were collected and analyzed from the Statistical Assessments while both quantitative data and qualitative data were collected from the Statistics Questionnaires. Concept maps provided both quantitative and qualitative data while semi-structured interviews provided qualitative data regarding pre-service elementary teachers' understanding of graphical representations.

Table 7

Descriptive and Inferential Statistics of Pre-Statistical Assessment Subscale and Overall Scores

Group	Range	Median	Rank Sum	*U*	*p*
Graphical Representations Subscale					
Control	18	31.5	237.0	132.0	0.779
Experimental	19	32.0	358.0		
Measures of Center Subscale					
Control	13	22.0	233.5	128.5	0.686
Experimental	18	23.0	361.5		
Overall Scores					
Control	23	37.0	225.0	120.0	0.483
Experimental	29	41.0	370.0		

Note: N = 14 for the control group; N = 20 for the experimental group

There were nine items on the Statistical Assessment dealing with graphical representations for a set of data (See Table 3). An independent samples Mann-Whitney U test was conducted on the post-treatment Statistical Assessment scores on these items at the $\alpha = 0.05$ level to determine if there was a significant difference between the experimental and control groups. Analysis revealed no significant difference found between the two groups, $U = 123.0$, p

> 0.05, with the sum of ranks equal to 367 for the experimental group and 228 for the control group. Since the Statistical Assessment was broken into two subscales—measures of center and graphical representations of data—an independent samples Mann-Whitney U test was also conducted to determine if there were any significant difference between the two groups in relation to the two subscales. Analysis revealed no significant differences found between the two groups, $U = 129.5$, $p > 0.05$, on the graphical representations subscale with the sum of ranks equal to 339.5 for the experimental group and 255.5 for the control group (see Table 8).

Table 8

Descriptive and Inferential Statistics of Post-Statistical Assessment Subscale and Overall Scores

Group	Range	Median	Rank Sum	*U*	*P*
Graphical Representations Subscale					
Control	23	27.0	255.5	129.5	0.713
Experimental	20	28.0	339.5		
Measures of Center Subscale					
Control	26	20.5	222.0	117.0	0.418
Experimental	24	23.0	373.0		
Overall Scores					
Control	31	36.5	228.0	123.0	0.551
Experimental	41	41.5	367.0		

Note: N = 14 for the control group; N = 20 for the experimental group

Analyses of qualitative data from the Statistics Assessments indicated that although participants in the both groups showed improvement and an increased understanding of graphical representations, the experimental group exhibited a somewhat greater understanding of how to read, use, and interpret different graphs. For instance, participants in the experimental group showed a deeper understanding of scatter plots than participants in the control group. For example, responses on a particular assessment item indicated that participants in the experimental group were adept at identifying correlation from a scatter plot and understanding how that correlation affected the data in question. Instead of simply looking at isolated values on a scatter plot, participants in this group were able to see the "big picture" as it related to the relationship between the two measured variables. One possible reason for this is that students manipulated and experimented with scatter plots in *Tinkerplots*™ more than other types of graphical representations. However, both groups demonstrated similar levels of understanding of how to use and interpret histograms or bar charts. In fact, neither group demonstrated any meaningful understanding of histograms with more than one case per class. In other words, students struggled with reading and using histograms with grouped classes and asymmetrical form. This is an unexpected finding for the experimental group considering the manipulative capabilities of the computer program, but can be explained by the fact that students were not required to create a grouped class histogram to complete any of the activities.

The Statistics Questionnaires provided both quantitative data from Likert-type items and qualitative data from comments and open-ended items. Three items on the Questionnaire dealt with graphical representations for a set of data. An independent samples Mann-Whitney U test was conducted on the post-treatment Statistics Questionnaire scores on these items at the $\alpha = 0.05$ level to determine if there was a significant difference between the experimental and control groups. Analyses revealed no significant difference found between the two groups, $U = 101.5$, $p > 0.05$, with the sum of ranks equal to 291.5 for the experimental group and 236.5 for the control group. Since the Statistics Questionnaire was broken into two subscales—measures of center and graphical representations of data—an independent samples Mann-Whitney U test was also conducted to determine if there were any significant difference between the two groups in relation to the two subscales. Analysis revealed no significant differences found between the two groups, $U = 104.5$, $p > 0.05$, on the graphical representations subscale with the sum of ranks equal to 294.5 for the experimental group and 233.5 for the control group (see Table 9).

Table 9

Descriptive and Inferential Statistics of Post-Statistics Questionnaire Subscale & Overall Scores

Group	Range	Median	Rank Sum	*U*	*p*
Graphical Representations Subscale					
Control	25	23.5	233.5	104.5	0.463
Experimental	16	24.0	294.5		
Measures of Center Subscale					
Control	25	21.5	234.0	104.0	0.453
Experimental	21	21.5	294.0		
Overall Scores					
Control	41	38.0	236.5	101.5	0.397
Experimental	31	36.0	291.5		

Note: N = 14 for the control group; N = 20 for the experimental group

Qualitative responses from participants in the control group indicated some confusion and lack of confidence regarding graphical representations of data. Although some participants felt that they could understand how to appropriately choose and interpret graphical representations, others were not completely sure. One participant professed, “I feel more confident about graphs, but I am still unsure how to choose the most practical graph” while another claimed, "I still need to work on which represents the best for certain data." Conversely, all participants in the experimental group indicated that they understood how to appropriately choose and interpret graphs. One participant in this group asserted, "I can tell, according to the data, the best way to view the information" while another said, "I can see a set of data and very quickly determine which graphical representation to use." Other participants in this group responded, "I am good at determining the most appropriate representation for a data set" and "I can figure out the best way to represent data." Moreover, the responses indicated an excitement about using graphs and deeper understanding about graphs. In many cases, *Tinkerplots*™ was given by participants as the key component in their learning about graphs. One of the participants claimed, "The computer program helped me learn how to organize the data better" while another responded, "I can play around on the computer with the different graphs and find which one suits the data best." This dynamic nature of the program is of benefit to students when they are attempting to determine the appropriateness of different graphs for different situations.

Tinkerplots™ surveys were included on only the post-Statistics Questionnaires for the experimental group (See Appendix D). Participants were asked to rate (on a five-point Likert-type scale—1 = strongly disagree and 5 = strongly agree) how *Tinkerplots*™ aided their learning in the course. Missing data on the surveys and concept maps were disregarded by the researcher and omitted from analyses. Three items dealt with graphical representations. Participants scored 3.76, 3.52, and 3.65, respectively on these items (See Table 10). This reflects a relatively strong agreement with the statements about the program being helpful in understanding graphical displays of data.

Each participant in the study also completed a concept map during a class period at the beginning and end of the data analysis module in the mathematics modeling course. Concept maps were described by the investigator to the participants at the beginning of the class and collected from the participants by the investigator at the end of the class period. The concept maps were then scored according to Table 5.

Table 10

Experimental Group Participants' Ratings From the Tinkerplots™ Surveys

	Minimum	Maximum	Mean	Std. Deviation
Understanding Measures	1.00	5.00	3.41	1.18
Understanding Graphs	1.00	5.00	3.76	1.15
Appropriate Choice of Graphs	1.00	5.00	3.52	1.12
Outlier Effect on Measures	1.00	5.00	3.06	1.48
Data Distributions	1.00	5.00	3.65	1.27
Appropriate Choice of Measures	1.00	4.00	2.71	0.92
Tinkerplots™ as a Learning Tool	1.00	5.00	3.71	1.26
Tinkerplots™ Useful in the Class	1.00	5.00	3.06	1.39

Note. N = 17

An independent samples Mann-Whitney U Test was conducted on post-treatment concept map scores on the mean number of concepts, the mean HSS (width + depth) score, and the mean number of chunks. SPSS was again used to see if there existed a significant difference between the experimental group and the control group. Analysis revealed that although the control group scored higher, on average, than the experimental group on number of concepts, $U = 62.0$, $p > 0.05$, on HSS, $U = 68.0$, $p > 0.05$, and on number of chunks, $U = 56.0$, $p > 0.05$, none of the differences were significant (see Table 11).

Since the Concept Maps were broken into two subscales—measures of center and graphical representations of data—an independent samples Mann-Whitney U test was also conducted to determine if there were any significant difference between the two groups in relation to the two subscales. Analysis revealed no significant differences found between the two groups on number of chunks on the graphical representations subscale. However, analysis revealed a significant difference between the groups on number of concepts, $U = 22.0$, $p = 0.02 < 0.05$, and on HSS, $U = 22.0$, $p = 0.02 < 0.05$, on the graphical representations subscale (see Table 12).

Table 11

Descriptive and Inferential Statistics of Post-Concept Maps Overall Scores

Group	Range	Median	Rank Sum	*U*	*P*
Number of Concepts					
Control	28	14.0	173.0	62.0	0.191
Experimental	11	13.5	233.0		
HSS = Width + Depth					
Control	13	11.5	167.0	68.0	0.308
Experimental	9	9.5	239.0		
Number of Chunks					
Control	3	2.0	179.0	56.0	0.109
Experimental	4	1.0	227.0		

Note: N = 10 for the control group; N = 18 for the experimental group

It must be noted that it was the control group that scored significantly better than the experimental group on these items, which was not expected. A possible reason for this is indicated through analysis of the qualitative data from the concept maps. It appears that participants from the experimental group, after their experience using *Tinkerplots*™, did not view graphs as a statistical concept, but only as a way to view or picture statistical data. Their view of statistics was reduced to numerical calculations and descriptive values.

Table 12

Descriptive and Inferential Statistics of Post-Concept Map Graphical Representations Subscale Scores

Group	Range	Median	Rank Sum	*U*	*P*
Number of Concepts					
Control	2	5	143.0	22.0	0.020
Experimental	5	4	88.0		
HSS = Width + Depth					
Control	2	6	143.0	22.0	0.020
Experimental	5	5	88.0		
Number of Chunks					
Control	1	0	125.0	40.0	0.082
Experimental	1	1	106.0		

Note: N = 10 for the control group; N = 18 for the experimental group

Wordle (Feinberg, 2009) was used to generate word clouds (See Appendix K) from the concept maps of participants in both groups. From studying the word clouds (See Table 13), two observations can be made. First, the control group demonstrated a greater increase in word cloud size from pre-treatment to post-treatment. Second, key terms missing from the post-treatment word clouds of the experimental group were involving graphical representations.

Concept maps from the same participant in the experimental group are included below. The first figure is a pre-treatment concept map (See Figure 3) and the second figure is a post-treatment concept map (See Figure 4). The concept maps were chosen because they were reflective of responses from the experimental group.

Table 13

Word Clouds

Group		
Control	 *Pre-Treatment Word Cloud*	 *Post-Treatment Word Cloud*
Experimental	 *Pre-Treatment Word Cloud*	 *Post-Treatment Word Cloud*

In Figure 3, a shallow understanding of statistics is displayed with random statistical concepts tethered to the central hub. In Figure 4, a deeper understanding of statistics is exhibited by grouping together related statistical concepts. Whereas Figure 3 represents the participant's statistical understanding as a mixed bag, Figure 4 represents the participant's statistical understanding as an organized, hierarchical structure. Comparison of the concept maps indicates that participants' understanding of particular statistical concepts improved over the course of the experimental time frame.

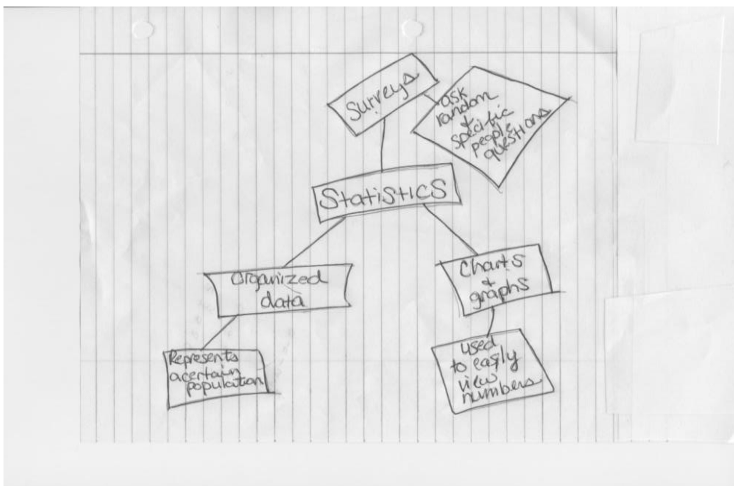


Figure 3. Pre-Treatment Concept Map from Participant in Experimental Group

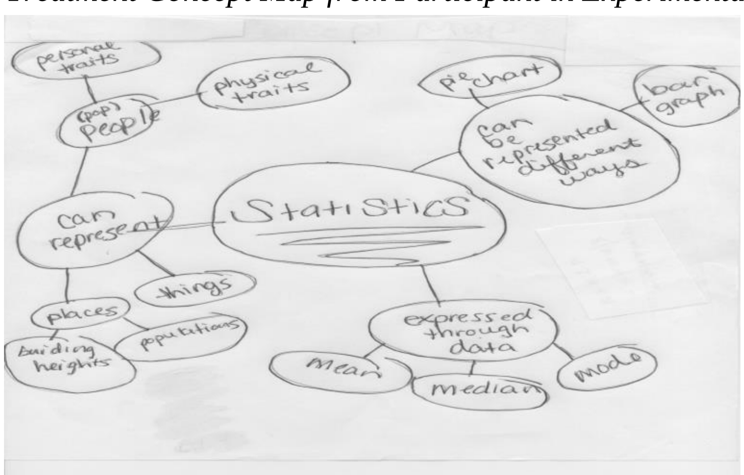


Figure 4. Post-Treatment Concept Map from Participant in Experimental Group

In interviews, participants from the experimental group were asked about the influence of *Tinkerplots™* on their understanding of graphs. To ensure confidentiality, interviewed participants in this study are referred to using pseudonyms. Nikki (not her real name) claimed that *Tinkerplots™* improved her ability to properly use graphical representations of data. The program helped her read the graphs and understand where the data was represented on the graphs. She felt like *Tinkerplots™* helped her put together graphs and she is very comfortable working with graphs now. She also mentioned that the program was helpful with the use of graphs as she was preparing for her state certification examinations.

Sandy also had some positive feedback regarding the influence of *Tinkerplots™* on her understanding of the use of graphs. She stated that the program had a more visual impact on learning about graphs than producing the graphs by hand. It was easier, faster, and enabled the user to see the data better. She suggested that "it's helpful because it's faster. You still learn the same things, it's just you don't have to take the time to make each graph yourself by hand." Kathy agreed with the others. She was particularly impressed with the multiple representations of the data that are available in *Tinkerplots™*. She enjoyed the options for graphing given by the program and the efficiency of the displays. She stated that the computer program gave her "more ideas on how to categorize things within a graph. It doesn't just have to be a basic bar graph or things like that. There are other ways of doing that so that it's easier to read. It helps on understanding how to label things, things I wouldn't have thought of."

Pre-Service Elementary Teachers' Understanding of Measures of Center

In order to examine pre-service elementary teachers' understanding of measures of center, the Statistical Assessments and Questionnaires consisted of items that dealt with participants' understanding of how to appropriately select, correctly use, and apply informal inference with measures of center. Quantitative and qualitative data were collected and analyzed from the Statistical Assessments and Statistics Questionnaires. Concept maps provided both quantitative and qualitative data while semi-structured interviews provided qualitative data regarding pre-service elementary teachers' understanding of measures of center.

There were five items on the Statistical Assessment dealing with measures of center for a set of data (See Table 3). An independent samples Mann-Whitney U test was conducted to determine if there was any significant difference between the two groups in relation to measures of center subscale. Analysis revealed no significant differences found between the two groups, $U = 117.0$, $p > 0.05$, on the measures of center subscale with the sum of ranks equal to 373.0 for the experimental group and 222.0 for the control group (see Table 8).

Analyses of qualitative data from the Statistics Assessments indicated that participants in the both groups demonstrated the same relative understanding of measures of center prior to and after the experimental period. So, it appears that *Tinkerplots*™ had little or no influence on experimental group participants' understanding of measures of center. Thus, both groups' understanding of measures of center was dependent on avenues of learning, not including the computer program. In other words, participants in the experimental group deepened their understanding of measures of center through classroom activities and discussions in the same way as participants in the control group.

The Statistics Questionnaires provided both quantitative data from Likert-type items and qualitative data from comments and open-ended items. Three items on the Questionnaire dealt with measures of center for a set of data. An independent samples Mann-Whitney U test was conducted on the post-treatment Statistics Questionnaire scores on these items at the $\alpha = 0.05$ level to determine if there was a significant difference between the experimental and control groups. Analysis revealed no significant difference found between the two groups on the measures of center subscale, $U = 104.0$, $p > 0.05$, with the sum of ranks equal to 294.0 for the experimental group and 234.0 for the control group (see Table 9).

Qualitative responses from participants in the control group indicated that some participants felt confident in their understanding of measures of center and their ability to correctly find and use those measures. One participant responded, “I feel confident in being asked to use measures of center to find data” while another claimed, “I know now what measures of center are and how to graph various sets of data. I believe I am now better equipped to do so.” Others in this group were still somewhat confused, and not as confident. One participant who felt this way asserted, “I feel better about choosing which, but since more than one can be used, it still gets tricky” while another professed, “I feel more confident actually knowing the measures of central tendency, but I sometimes second guess myself.” Participants in the experimental group felt more confident in their understanding and their ability to appropriately find and use measures of center. One participant from this group claimed, “I can look and see what value represents the data best” and another said, “I am able to and comfortable with finding measures of center.” However, one response from a participant in the experimental group exhibits a potential problem in using *Tinkerplots*™ in learning about measures of center. She shared, “I understand how to do it on the computer, but on paper I have a harder time.” This suggests that this student, and possibly others, may not have a deep understanding of measures of center, but are simply depending on the computer program to calculate the values for them.

Tinkerplots™ surveys were included on only the post-Statistics Questionnaires for the experimental group (See Appendix D). Participants were asked to rate, on a 5-point Likert-type scale (1 = strongly disagree and 5 = strongly agree), how *Tinkerplots*™ aided their learning in the course. Three items dealt with measures of center. Participants scored 3.41, 3.06, and 2.71, respectively on these items (See Table 10). This reflects relatively strong agreement with the statement about the program being helpful in understanding measures of center, but relatively weak agreement with the statements about the program being helpful in understanding outliers' effect on measures of center and appropriate choices of measures of center.

Since the Concept Maps were broken into two subscales, measures of center and graphical representations of data, an independent samples Mann-Whitney U test was conducted to determine if there was any significant difference between the two groups in relation to the measures of center subscale. Analysis revealed no significant differences found between the two groups on number of concepts, HSS, or number of chunks (see Table 14).

Table 14

Descriptive and Inferential Statistics of Post-Concept Map Measures of Center Subscale Scores

Group	Range	Median	Rank Sum	*U*	*P*
Number of Concepts					
Control	5	6	162.0	73.0	0.399
Experimental	7	4	244.0		
HSS = Width + Depth					
Control	3	5	158.5	76.5	0.490
Experimental	4	5	247.5		
Number of Chunks					
Control	1	0	146.0	89.0	0.955
Experimental	1	0	260.0		

Note: N = 10 for the control group; N = 18 for the experimental group

Table 15

Word Cloud Concept Counts for Measures of Center

Group	Mean	Median	Mode	Midrange
Control	8	10	10	7
Experimental	18	17	18	10

Wordle (Feinberg, 2009) was used to generate word clouds (See Appendix J) from the concept maps of participants in both groups. Considering only concepts from the maps that dealt with measures of center, participants in the experimental group had higher frequencies on every concept (See Table 15).

In interviews, when asked how *Tinkerplots*™ influenced their understanding of the use of measures of center, responses were varied. Nikki expressed that she had never been good at finding measures of center. She claimed that the program was helpful, but that she already knew how to figure measures of center out. She shared, “On *Tinkerplots*™, you just click a button and it shows it to you. I mean it helped out, but not too much.” Sandy didn’t think the program was helpful at all regarding measures of center usage. When asked why, she responded, “I don’t know. I just wasn’t paying attention to them or I didn’t understand using them, but to me, the program was just making the graphs different.” Kathy conveyed a clearer message in her response. She explains that it is important to figure out how to use measures of center on your own, but that *Tinkerplots*™ made it very quick and easy, almost too easy. She asserted that it was amazing to be able to click a button and find a measure of center quickly, but knowing how to find them by hand would be more helpful in knowing how to use them.

Concluding Remarks

The analysis of the data presented in this chapter indicates that the influence of *Tinkerplots*™ on pre-service elementary teachers' understanding of graphical representations and measures of center is variable and minimal. Quantitative and qualitative data analysis of the Statistical Assessments, Statistics Questionnaires, and Concept Maps, along with qualitative data from the interviews, would seem to indicate that the influence of *Tinkerplots*™ was positive regarding participants' understanding of graphical representations. However, the same analysis also seems to indicate that the influence of *Tinkerplots*™ on participants' understanding of measures of center is negligible. Although some reasons for this result are discussed, it is clear that more study is required to accurately determine the *Tinkerplots*™ influence. As indicated by the data, the program seemed to be helpful for some participants while neither helpful nor unhelpful for others. This type of program may be more beneficial for use in customizing to individual students' learning styles. It is also possible that the educational environment, in which the program is housed, may affect the possible influence that *Tinkerplots*™ has on statistical learning.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The importance of teacher statistical literacy is well documented in literature. Pre-service elementary teachers need to be statistically literate to minimize vulnerability in a computer age (Steen, 1997). They need to be responsible citizens (Wallman, 1993) and they need to function independently in their profession regarding data to which they are exposed (Watson & Callingham, 2003). When considering that teachers are also in the crucial position of having a direct influence on their own student's statistical learning, the importance is amplified. Also, new technology is being developed that can transform the educational learning environment. The potential educational benefits that can result from an effective use of dynamic statistical software program have been examined by numerous mathematics educators, including Lane-Getaz (2005), Franklin & Garfield (2006), and Lane & Tang (2000). Therefore, this research study investigated the influence of a computer software package (*Tinkerplots*™) on pre-service elementary teachers' statistical literacy.

The purpose of the research was to explore the influence of the use of *Tinkerplots*™ in a mathematics modeling classroom on pre-service teachers' level of understanding of data analysis. In particular, the study investigated the influence that *Tinkerplots*™ had on pre-service teachers' understanding of graphical representations of data and measures of center. With this information, teachers may be able to offer their students an alternative approach to learning statistical concepts.

The research questions guiding this study were:

1. How does the use of *Tinkerplots™* influence preservice elementary teachers' understanding of graphical representations of data (i.e., selection, use, and ability to make inference)?
2. How does the use of *Tinkerplots™* influence preservice elementary teachers' understanding of measures of center (i.e., selection, use, and ability to make inference)?

Both quantitative and qualitative data were collected using a concurrent embedded strategy of a mixed methods design. Thirty-four pre-service elementary teachers completed pre/post Statistical Assessments, Statistics Questionnaires, concept maps, and demographic surveys during the experimental time frame. In addition, a semi-structured interview was conducted at the conclusion of the experimental module with 3 participants from the experimental group. Quantitative and qualitative data were collected from Statistical Assessments, Statistics Questionnaires and concept maps, while qualitative data were collected from interviews. This data were then analyzed in order to answer the research questions regarding the influence of *Tinkerplots™* on participants' understanding of graphical representations and measures of center.

Pre-Service Elementary Teachers' Understanding of Graphical Representations

The first research question sought to investigate the influence of *Tinkerplots™* on preservice elementary teachers' understanding of graphical representations of data. Quantitative and qualitative data were collected and analyzed from the Statistical Assessments and Statistics Questionnaires. Concept maps provided both quantitative and qualitative data while semi-structured interviews provided qualitative data regarding pre-service elementary teachers' understanding of graphical representations.

Analysis of the quantitative data from the Statistical Assessments revealed no significant differences found between the two groups on the graphical representations subscale which suggests that *Tinkerplots™* did not significantly influence pre-service elementary teachers' understanding of graphical representations of data. This is an unexpected result when compared to results from previous studies by Steinke (2005), Bakker & Frederickson (2005), and Keller (2005). Analysis of qualitative data from the Statistics Assessments reveals that participants in the both groups showed improvement and an increased understanding of graphical representations. Although participants in the experimental group exhibited an understanding of how to read, use, and interpret graphs in different ways, it is unclear what level of influence *Tinkerplots™* had, if any.

Analysis of the quantitative data from the Statistics Questionnaires revealed no significant differences found between the two groups on the graphical representations subscale, again suggesting that *Tinkerplots™* had little influence on pre-service elementary teachers' understanding of graphical representations. However, analyses of qualitative data from the Statistics Questionnaires suggest that participants *felt* like *Tinkerplots™* influenced their understanding of graphs. Participants from the control group exhibited some confusion and lack of confidence regarding graphical representations. However, all participants in the experimental group indicated that they understood how to appropriately choose and interpret graphs.

Tinkerplots™ surveys were included on only the post-Statistics Questionnaires for the experimental group. Participant scores on the surveys reflected a relatively strong agreement with the statements about the program being helpful in understanding graphical displays of data. Again, the participants were under the impression that the program was aiding their understanding, although analysis of the quantitative data does not necessarily support this.

Analysis of quantitative data from the concept maps revealed that no significant differences were found between the two groups on number of chunks on the graphical representations subscale, which reinforces what was revealed by other quantitative analysis. However, analysis revealed a significant difference between the groups on number of concepts and *HSS* on the graphical representations subscale, with the control group scoring better than the experimental group. Qualitative analyses of the concept maps suggest that many participants in the experimental group simply did not include any kind of graphical representation as a concept on their maps. It is unclear why those participants submitted completed post-concept maps without including graphs, particularly when the same participants included graphs on the pre-concept maps. It is possible that participants from the experimental group, after their experience using *Tinkerplots™*, did not view graphs as a statistical concept, but only as a way to view or picture statistical data. However, there is not enough data to support this conclusion.

In interviews, participants were asked about the influence of *Tinkerplots™* on their understanding of graphs. All three participants gave feedback that implied a positive response regarding the program's influence. They claimed that *Tinkerplots™* improved their ability to properly read, interpret and use graphs. They also indicated that the program was easy to use and enabled the user to visualize the data in ways that were unexpected and helpful. Thus, the qualitative data from the interviews reinforces the suggestion that participants in the experimental group *felt* like the *Tinkerplots™* program was helping them understand graphical representations.

Pre-Service Elementary Teachers' Understanding of Measures of Center

The first research question sought to investigate the influence of *Tinkerplots™* on preservice elementary teachers' understanding of measures of center. Quantitative and qualitative data were collected and analyzed from the Statistical Assessments and Statistics Questionnaires. Concept maps provided both quantitative and qualitative data while semi-structured interviews provided qualitative data regarding pre-service elementary teachers' understanding of measures of center.

Analysis of the quantitative data from the Statistical Assessments, Statistics Questionnaires, and concept maps revealed no significant differences found between the two groups on the measures of center subscale. This suggests that *Tinkerplots*™ had little or no influence on participants' understanding of measures of center. This is reinforced by analyses of qualitative data from the Statistics Assessments, which indicated that participants in the both groups demonstrated the same relative understanding of measures of center prior to and after the experimental period. Analyses of qualitative data from the Statistics Questionnaires suggest that whether or not participants truly understood measures of center, participants in the experimental group *felt more confident* in their understanding and their ability to appropriately find and use measures of center. Thus, participants in the experimental group *believed* that *Tinkerplots*™ was influential in their understanding of measures of center.

Tinkerplots™ surveys were included on only the post-Statistics Questionnaires for the experimental group. Participant scores on the surveys reflected a relatively strong agreement with the statement about the program being helpful in understanding measures of center, but relatively weak agreement with the statement about the program being helpful in understanding outliers' affect on and the appropriate choice of measures of center. This reinforces the idea that participants *felt* that *Tinkerplots*™ influenced their understanding of measures of center.

In interviews, participants were asked about the influence of *Tinkerplots*™ on their understanding of measures of center. All three participants gave feedback indicating that the program did not influence their understanding of measures of center. They asserted that *Tinkerplots™* was helpful only in finding measures of center quickly and easily. These results are interesting because they do not reinforce the suggestion from other qualitative analysis that *Tinkerplots™* influences participant understanding of measures of center. It is unclear why this contention exists and more research is required in order to address this issue.

Implications

The results of this study have two implications for statistics education, particularly that of pre-service elementary teachers. First, this study found that *Tinkerplots™* had little or no influence on pre-service teachers' understanding of graphical representations. This finding would seem to be in conflict with results from the studies of Steinke (2005), Bakker & Frederickson (2005), and Keller (2005). However, it is important to note that two of the three previous studies (Steinke, 2005; Bakker & Frederickson, 2005) were not similar in design to this study, while the third study (Keller, 2005) consisted of a general review of the software. The studies by Steinke (2005) and Bakker & Frederickson (2005) were case studies that involved specific middle grade classes which were introduced to the software and began using it to complete activities during an observational time period. Data for the studies consisted of observations of students using the software in class. Qualitative analyses of the observational data were then completed to determine the effect of *Tinkerplots™*. Differences in study design could explain the contrasting results, but further studies are necessary in order to determine if *Tinkerplots™* has an influence on student learning about graphical representations. However, participants in the study *believed* that *Tinkerplots™* had a positive influence and helped them to understand graphical representations. Comments from participants indicated an appreciation for the dynamic nature of the program which allowed them to manipulate graphs and helped them to make sense of the data that was represented. The participants felt that *Tinkerplots™* was instrumental in enabling them to determine which type of graph would help them answer questions in the activities. Further investigation is needed for determining why participants believe that their understanding is improving as a result of the program even when an improved understanding is not exhibited.

Second, this study found that *Tinkerplots™* had little or no influence on pre-service teachers' understanding of measures of center, which is also not in alignment with results from previous studies (Steinke, 2005; Bakker & Frederickson, 2005; Keller, 2005). Again, differences in study design could explain the contrasting results, but further studies are necessary in order to determine if *Tinkerplots™* has an influence on student learning about measures of center. Qualitative results and responses from participants in the experimental group were incongruous. Questionnaire responses indicated that participants *believed* that *Tinkerplots™* had a positive influence and helped them understand measures of center. However, interview responses indicated that the program did not help them understand, but only helped them *calculate* the measures of center. This suggests that many participants were equating ease of calculation with better understanding. Thus, it is important for mathematics educators to communicate this difference to their students and appropriately use educational tools and technology to enhance their students' understanding of measures of center.

Recommendations for Future Research

While data analysis revealed interesting findings regarding pre-service elementary teachers' statistical literacy, and the influence of *Tinkerplots™*, more research is needed to determine what level of influence *Tinkerplots™* has on learners. Recommendations for future research from this study leads to the following future research studies:

- A newer version of *Tinkerplots*™ has now been developed. It would be beneficial to repeat the experiment using the newer version of the software to possibly compare the influence of the older and newer versions.
- Participants in this study used *Tinkerplots*™ for six weeks. It would be beneficial to investigate the influence of the program on participants' understanding of statistics when they are exposed to *Tinkerplots*™ for the entire semester. Results could vary if the class were to take place in a computer lab housed with learning stations designed in such a way to encourage collaboration and discussion. Prolonged experience with the computer program and the lab setting could help alleviate any participant stress or confusion when *Tinkerplots*™ is introduced.
- One particular consideration that received only marginal attention was that of learning styles. While there is no definitive answer to whether learning styles play a part in the learning of students, it would be beneficial to examine the influence of *Tinkerplots*™ through the lens of learning styles. For instance, the influence of *Tinkerplots*™ may be more pronounced in students that are visual and less pronounced in students that are tactile or kinesthetic. When asked if how students with different learning styles would respond to *Tinkerplots*™, interviewed participants indicated that they believed the program would be more helpful to certain kinds of learners. Thus, there is a need to investigate to determine the effect of learning styles, if any, on this type of study.
- Another consideration for future study involves Technological Pedagogical Content Knowledge (TPACK). The focus of this study did not include any discussion of the knowledge that teachers need to teach technology effectively. However, it is related

to this study because pre-service teachers will one day be actual teachers responsible for helping their own students gain a sufficient level of statistical literacy. Since *Tinkerplots*™ is a program that is designed for the primary grades, it would make sense that a teacher may want to incorporate the program into her curriculum. This would require an ability to effectively integrate technology for pedagogy around statistics, which is what the TPACK framework is for. Thus, it would be of benefit to expand this study and investigate the pedagogical content knowledge (PCK) of elementary teachers as they integrate the "how", technology, with the "what", statistics.

Technology is transforming mathematics and statistics education and research on the impact of technology on learning mathematics and statistics is growing. Future research needs to examine the connections and relationships among learners, educators, technological tools, and learning environments. In doing so, researchers and educators can help determine the best way to enhance the learning that takes place in their classroom.

Concluding Remarks

The need for statistically literate teachers has been well documented in the literature (Steen, 1997; Wallman, 1993). However, it is unclear if pre-service teachers have achieved an acceptable level of statistical literacy when they complete their mathematics modeling courses. Mathematics educators, who are responsible for the statistical literacy of pre-service teachers, need to have every opportunity to enhance learning opportunities for their students. Technology can provide this opportunity, but only if it used appropriately. Not every new technology is effective in the classroom, even if it was designed as an educational tool. Mathematics educators must be cautious when evaluating computer software and determine if the program is going to meet their educational needs. Some computer programs will look valuable on display, but be ineffective in a specific classroom setting for any number of reasons. The success of *Tinkerplots*™ in the classroom is well-documented, although not necessarily in this study, and the potential exists for enhanced learning opportunities using the program. Further research is needed and recommended. However, for *Tinkerplots*™ to be effective in an educational environment, the educator must determine if it will meet the educational needs of her students and if it will be used appropriately to meet those needs.

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APPENDICES

APPENDIX A

STATISTICAL ASSESSMENT

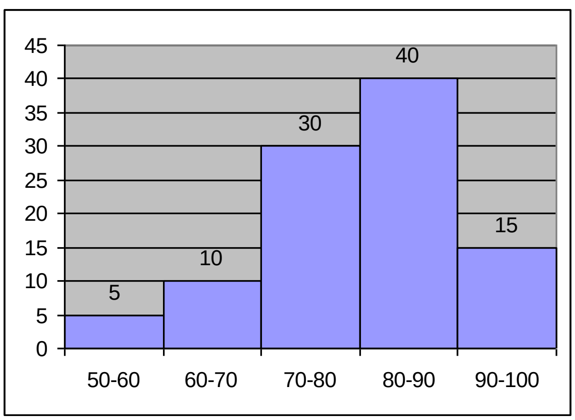
1. In a particular neighborhood of a township, 100 families have a mean household income of $60,000. If a new family moves in to the neighborhood with a household income of $250,000, what measure of center is most affected? If you were required to report the *average* household income of this neighborhood, which measure of center would you choose?

   Explain your reasoning.

2. Suppose you own a hat shop and decide to order hats in only one size for the coming season. To decide which size to order, you look at last year's sales figures, which are itemized according to size. Which measure of center should you use?

   Explain your reasoning.

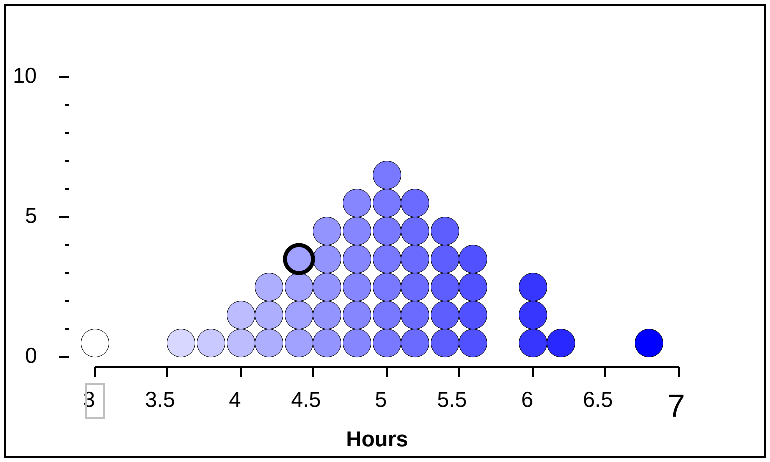
3. The manager of the local BOWL-MORE was interested in the distribution of bowling scores for first-time bowlers. He collected information from the past year and constructed the histogram below.



   Using this graph, what was the approximate median score for this group of first-time bowlers?

   Explain your reasoning.

4. A member of the Panasonic quality control department randomly chose a box containing fifty 9-volt batteries from a lot containing 20,000 such boxes. The batteries were tested to determine their life under normal use. The results are shown below.



Using this graph what is the approximate modal life of the 50 batteries?

Explain your reasoning.

5. Two college roommates have a monthly budget of $1500.00. The table below shows where the money is spent each month.

ITEM	AMOUNT
Food	$500
Rent	$450
Clothing	$150
Books	$150
Entertainment	$130
Other	$120

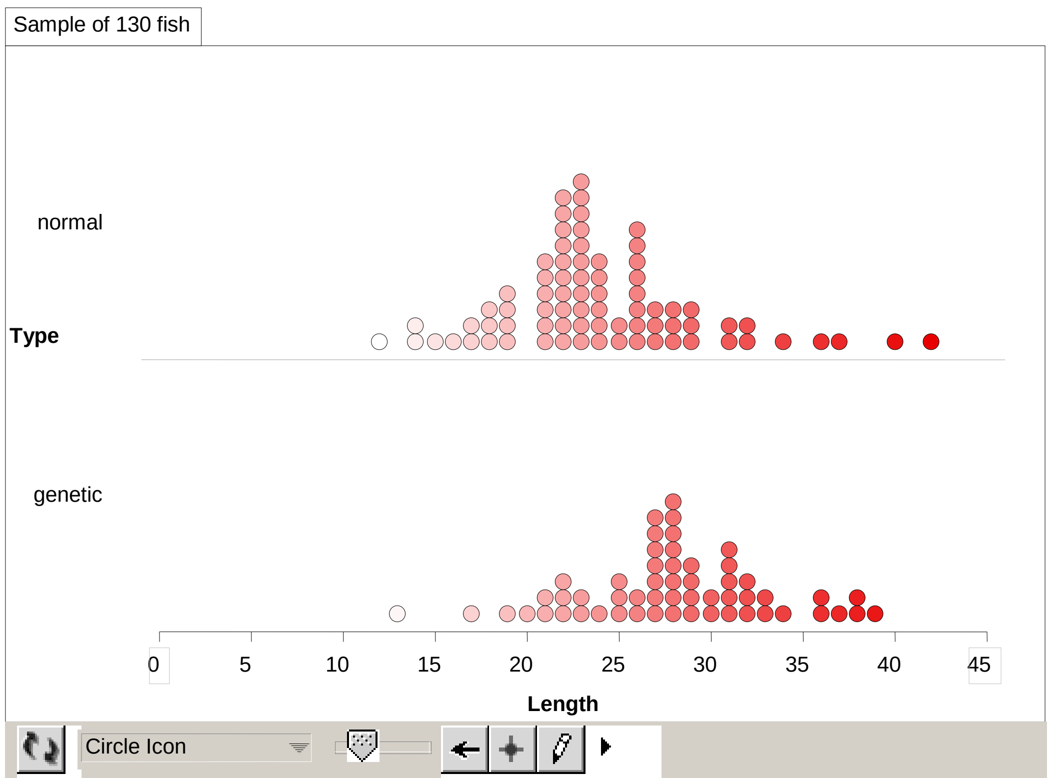
What would be the most appropriate graphical display for the data?

Explain your reasoning.

6. According to the following graph, do genetically engineered fish tend to grow longer than normal fish?

   If you concluded that the genetically engineered fish do tend to grow longer, about how much longer than the normal fish do they tend to be?

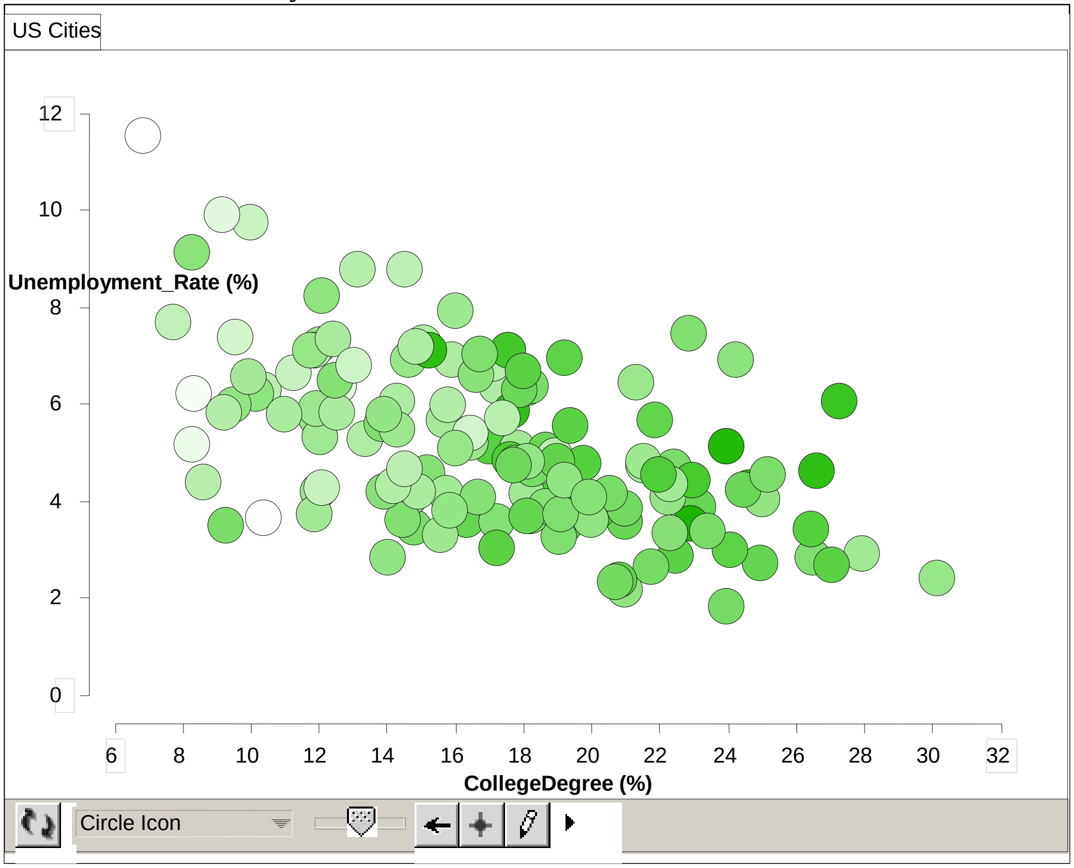
   Does it appear that the genetically engineered fish are any more or less variable in length than the normal fish?



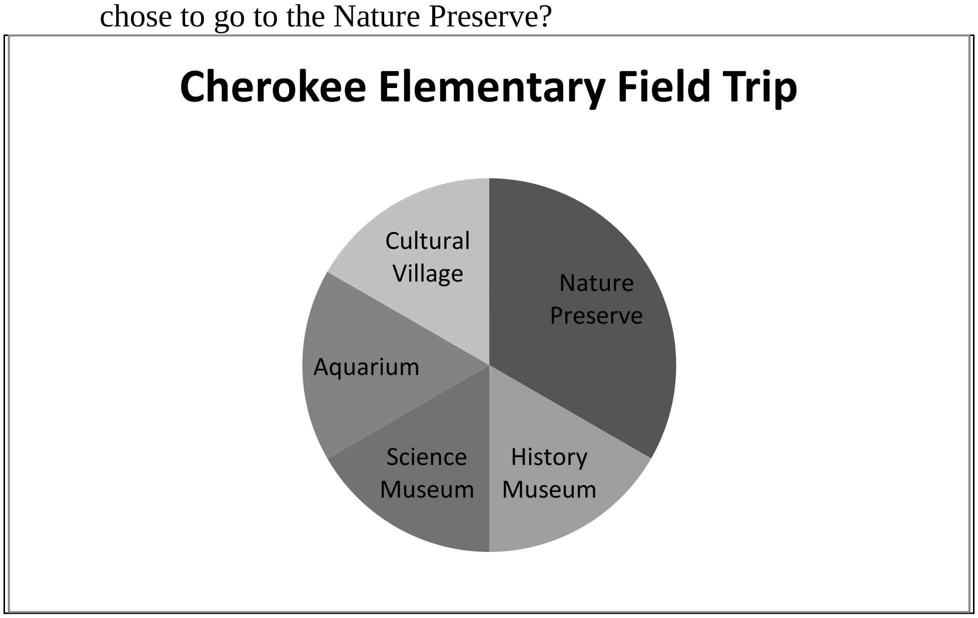
7. The given data represent total car sales for Johnson's car lot from January through June. What is the appropriate graph to illustrate this data? Explain your reasoning and draw the graph.

MONTH	JAN	FEB	MAR	APR	MAY	JUN
No. of cars sold	90	86	92	98	90	100

8. Can you make any inferences using the following scatter plot? If so, what inferences can you make?



9. Cherokee Elementary School conducted a poll of 300 fourth graders to determine where to go on a field trip. Based on the following chart, how many students chose to go to the Nature Preserve?



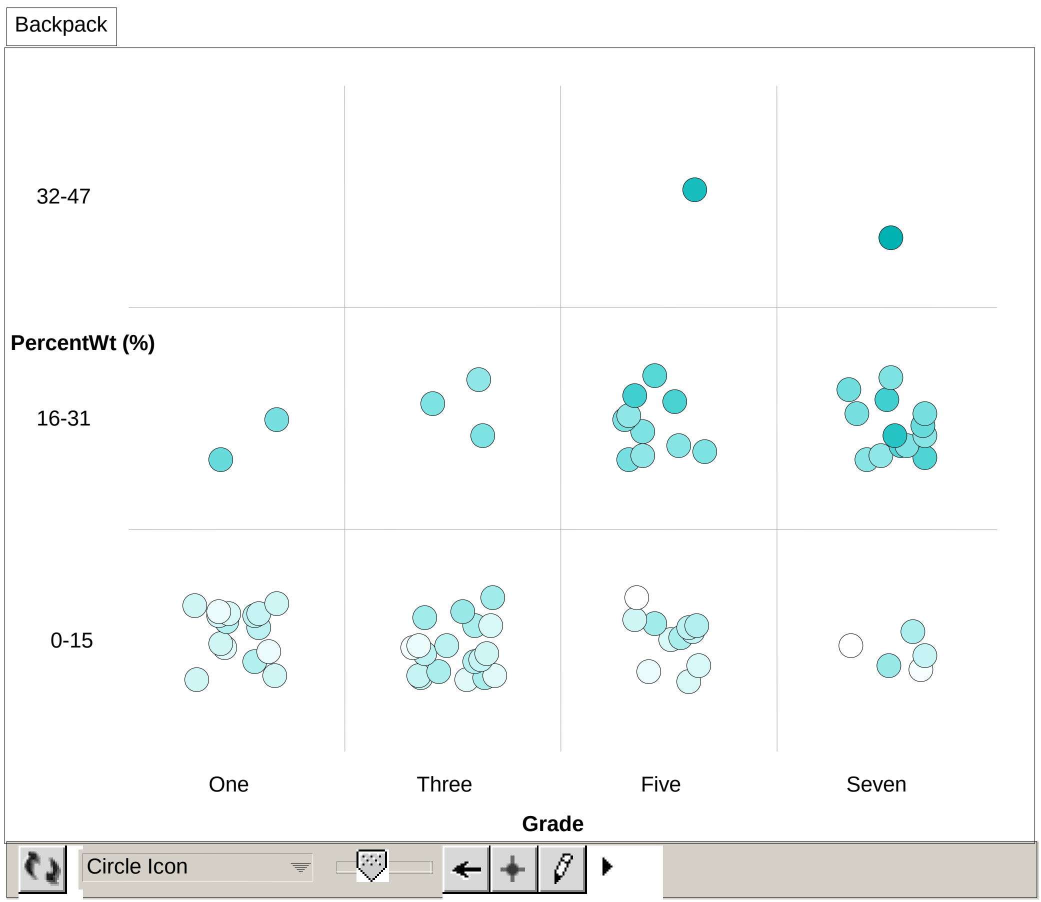
10. Using the following graph, answer the following questions:

a. What percentage of students carry backpacks that are too heavy (more than 15% of their body weight)?

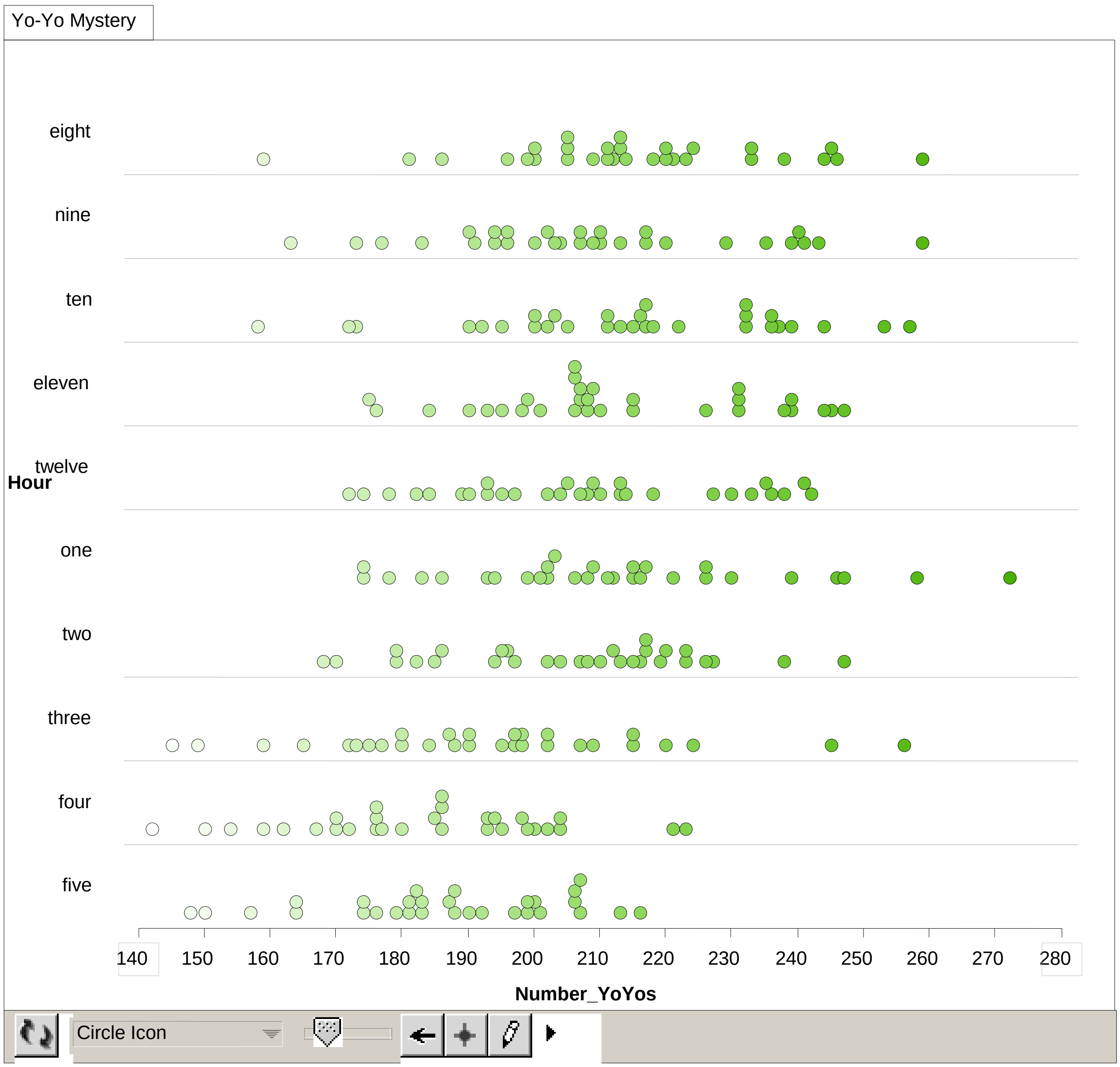
b. What percentage of students in higher grades (grades 5 and 7) carry backpacks that are too heavy?

c. What percentage of students in lower grades (grades 1 and 3) carry backpacks that are too heavy?

d. Which students tend to carry backpacks that weigh more for their body weight—students in higher grades or students in lower grades?



11. The following graph shows the number of yo-yos produced by a yo-yo machine at a factory between the hours of 8:00 pm and 5:00 am. A break-in occurred at the factory during the night cutting off power momentarily. When this happened, the yo-yo machine reset and started producing yo-yos at a slower rate. Based on the data below, can you determine when the break in occurred?



APPENDIX B

PRE-QUESTIONNAIRE

1. In the space provided below, explain your understanding of measures of center.

2. In the space provided below, explain your understanding of graphical displays of data.

3. On a scale of 1 to 10 with 1 being very poor and 10 being very good, how would you rate your ability to determine measures of center for various sets of data?

   1 2 3 4 5 6 7 8 9 10

   Very poor *Very good*

   Please explain:

4. On a scale of 1 to 10 with 1 being very poor and 10 being very good, how would you rate your ability to represent graphically a variety of sets of data?

   1 2 3 4 5 6 7 8 9 10

   Very poor *Very good*

   Please explain:

5. On a scale of 1 to 10 with 1 being very poor and 10 being very good, how would you rate your ability to determine the most appropriate graphical representation for a set of data?

1 2 3 4 5 6 7 8 9 10

Very poor *Very good*
Please explain:

6. On a scale of 1 to 10 with 1 being very poor and 10 being very good, how would you rate your ability to determine the most appropriate measure of central tendency (statistic) to represent a set of data?
1 2 3 4 5 6 7 8 9 10

Very poor *Very good*

Please explain:

7. On a scale of 1 to 10 with 1 being very poor and 10 being very good, how would you rate your ability to use informal inference with measures of center or graphical representations?
1 2 3 4 5 6 7 8 9 10

Very poor *Very good*

Please explain:

APPENDIX C

POST-QUESTIONNAIRE (CONTROL)

1. In the space provided below, explain your understanding of measures of center.

2. In the space provided below, explain your understanding of graphical displays of data.

3. On a scale of 1 to 10 with 1 being very poor and 10 being very good, how would you rate your ability to determine measures of center for various sets of data?

   1 2 3 4 5 6 7 8 9 10

   Very poor *Very good*

   Please explain:

4. On a scale of 1 to 10 with 1 being very poor and 10 being very good, how would you rate your ability to represent graphically a variety of sets of data?

   1 2 3 4 5 6 7 8 9 10

   Very poor *Very good*

   Please explain:

5. On a scale of 1 to 10 with 1 being very poor and 10 being very good, how would you rate your ability to determine the most appropriate graphical representation for a set of data?

1 2 3 4 5 6 7 8 9 10

Very poor *Very good*

Please explain:

6. On a scale of 1 to 10 with 1 being very poor and 10 being very good, how would you rate your ability to determine the most appropriate measure of central tendency (statistic) to represent a set of data?

1 2 3 4 5 6 7 8 9 10

Very poor *Very good*

Please explain:

7. On a scale of 1 to 10 with 1 being very poor and 10 being very good, how would you rate your ability to use informal inference with measures of center or graphical representations?

1 2 3 4 5 6 7 8 9 10

Very poor *Very good*

Please explain:

8. Thinking back on the learning experiences in the course(activities, experiments, surveys, etc.) dealing with data analysis, which do you feel had the **greatest** impact on your ability to:

   1) Analyze and interpret measures of center?

   2) Represent data graphically?

   3) Use informal inference?

9. Thinking back on the learning experiences in the course(activities, experiments, surveys, etc.) dealing with data analysis, which do you feel had the **least** impact on your ability to:

   1) Analyze and interpret measures of center?

   2) Represent data graphically?

   3) Use informal inference?

APPENDIX D

POST-QUESTIONNAIRE (EXPERIMENTAL)

1. In the space provided below, explain your understanding of measures of center.

2. In the space provided below, explain your understanding of graphical displays of data.

3. On a scale of 1 to 10 with 1 being very poor and 10 being very good, how would you rate your ability to determine measures of center for various sets of data?

   1 2 3 4 5 6 7 8 9 10

   Very poor *Very good*

   Please explain:

4. On a scale of 1 to 10 with 1 being very poor and 10 being very good, how would you rate your ability to represent graphically a variety of sets of data?

   1 2 3 4 5 6 7 8 9 10

   Very poor *Very good*

   Please explain:

5. On a scale of 1 to 10 with 1 being very poor and 10 being very good, how would you rate your ability to determine the most appropriate graphical representation for a set of data?

1 2 3 4 5 6 7 8 9 10

Very poor *Very good*

Please explain:

6. On a scale of 1 to 10 with 1 being very poor and 10 being very good, how would you rate your ability to determine the most appropriate measure of central tendency (statistic) to represent a set of data?

1 2 3 4 5 6 7 8 9 10

Very poor *Very good*

Please explain:

7. On a scale of 1 to 10 with 1 being very poor and 10 being very good, how would you rate your ability to use informal inference with measures of center or graphical representations?

1 2 3 4 5 6 7 8 9 10

Very poor *Very good*

Please explain:

8. Thinking back on the learning experiences in the course(activities, experiments, surveys, *tinkerplots*, etc.) dealing with data analysis, which do you feel had the **greatest** impact on your ability to:

1) Analyze and interpret measures of center?

2) Represent data graphically?

3) Use informal inference?

9. Thinking back on the learning experiences in the course(activities, experiments, surveys, *tinkerplots*, etc.) dealing with data analysis, which do you feel had the **least** impact on your ability to:

1) Analyze and interpret measures of center?

2) Represent data graphically?

3) Use informal inference?

***TINKERPLOTS* SURVEY**

Please respond to each of the following items using the following scale:

5 = Strongly Agree 4 = Agree 3 = No Opinion 2 = Disagree 1 = Strongly Disagree

1.	*Tinkerplots* helped me to gain a better understanding of measures of center. Please explain.	1	2	3	4	5
2.	*Tinkerplots* helped me to gain a better understanding of the different types of graphs used to represent sets of data. Please explain.	1	2	3	4	5
3.	*Tinkerplots* helped me to gain a better understanding of which type of graph is most appropriate for a set of data. Please explain.	1	2	3	4	5
4.	*Tinkerplots* helped me to gain a better understanding of the effect of outliers on a set of data. Please explain.	1	2	3	4	5
5.	*Tinkerplots* helped me to gain a better understanding of how data are distributed. Please explain.	1	2	3	4	5
6.	*Tinkerplots* helped me to gain a better understanding of which measure of central tendency is most appropriate for a set of data. Please explain.	1	2	3	4	5
7.	*Tinkerplots* is a powerful tool for learning. Please explain.	1	2	3	4	5
8.	*As a future teacher, I can see Tinkerplots* being used successfully in my class to help students learn statistics. Please explain.	1	2	3	4	5

APPENDIX E

INTERVIEW PROTOCOL QUESTIONS

1. What do you think of when I say, “statistics?”

2. Tell me about your experiences studying statistics prior to taking this course.

3. What are your most memorable experiences involving statistics?

4. How important is it for pre-service elementary teachers to understand statistical concepts—particularly graphical representations of data?

5. How has your experience with statistics activities influenced the way you feel about including statistical concepts into elementary curriculum?

6. If you were designing a statistics course for pre-service elementary teachers, what kinds of activities would you include?

7. This semester you had the opportunity to use Tinkerplots on your assignments. How would you rate your experience?

8. How did the use of Tinkerplots influence your understanding of graphical representations?

9. How did the use of Tinkerplots influence your understanding of measures of center?

10. How effectual was the inclusion of Tinkerplots into the course curriculum?

11. I have asked you a lot of questions during this interview. Is there anything that you would like to add or that you wish I had asked you but didn’t?

APPENDIX F

RESEARCHER'S RECRUITMENT SCRIPT

I am conducting a research study to explore the impact of Tinkerplots on Preservice Elementary Teachers' understanding of measures of center and graphical representations.

As prospective teachers, I would welcome your participation in this study. In this research study you will be asked to complete a demographic profile, a Statistics Pre- and Post-Assessment, a Statistics Pre-and Post-Questionnaire which may or may not include a Tinkerplots survey. The completion of the Assessments involves reading and responding to items that reflect your understanding of measures of center and graphical representations. The completion of the Questionnaires involves reading and responding to items that reflect how you rate your understanding of measures of center and graphical representations. It will take approximately 20 minutes to complete each Assessment and 20 minutes to complete each Questionnaire. Additionally, some participants will be asked to participate in video recorded interviews.

Your participation in this research study is invaluable and will help give mathematics educators insights into how pre-service elementary teachers think about measures of center and graphical representations of data.

Thank you!

APPENDIX G

INFORMED CONSENT DOCUMENT

Project Title: Impact of Tinkerplots on Preservice Elementary Teachers' Understanding of Measures of Center and Graphical Representations

Investigators: PI: Mr. Luke Foster, M.S., Ph.D. Candidate
Advisor: Dr. Juliana Utley, Ph.D., Assistant Professor, STCL: Oklahoma State University

Purpose: The primary purpose of this study is to determine through both qualitative and quantitative methodology whether the use of *Tinkerplots™* in a mathematics education classroom significantly improves pre-service elementary teachers' level of understanding of data analysis. In particular, the study investigates the effect, if any, that *Tinkerplots™* has on pre-service elementary teachers' understanding of how to appropriately select, use and make informal inferences from both graphical representations of data and measures of center.

Procedure: Participants will be asked to complete a pre/post Statistics Assessment and a pre/post Statistics Questionnaire. This will be administered at the beginning and end of the semester to all students who choose to participate. For those who agree by signing this consent form, I will examine your assessments/questionnaires as a part of my study. It will take you approximately 50 minutes at the beginning and end of the semester to complete the Statistics Assessment and the Questionnaire.

Additionally, from those of you who are willing to be interviewed I will select approximately 6 people to interview. You will be given an opportunity at the end of this consent form for you to volunteer for these interviews. These interviews will be video recorded in order for me to capture your thoughts and work as you respond to questions and solve problems. The interview will take approximately 10 minutes and will be scheduled at your convenience. These videos will only be viewed by researchers involved in this study.

Your instructor will not see the video or see my analysis of your responses of the assessments.

Risks: There are no known risks associated with this project which are greater than those ordinarily encountered in daily life. Your grade will not be affected by the results of this test or your agreement/disagreement to participate.

Benefits: While there are no expected benefits for you directly, your participation will help inform mathematics educators on the best ways to teach statistics.

Confidentiality: Your identity will remain confidential. Each participant will be assigned unique identification number, known only to the investigator, which will allow for identifying participants pre- and post- assessment scores, questionnaire responses, and interview choices. A list of names and ID numbers will be maintained by the investigator until the conclusion of the research project. The records of this study will be kept private. Any written results will discuss group findings and will not include information that will identify you. Research records will be stored securely and only researchers and individuals responsible for research oversight will have access to the records. It is possiblethat the consent process and data collection will be observed by research oversight staff responsible for safeguarding the rights and wellbeing of people who participate in research. Data collected from the study will remain locked in Mr. Foster's office and kept for 24 months. At that time all the data will be effectively destroyed. Hard copies will be shredded, digital files will be deleted and backups destroyed.

Compensation: There is no compensation for participation in the study.

Participant Rights: Your participation in this project is strictly voluntary. It will in no way affect your grade in MATH 3443. You may decline to participate at any time. If you have any questions or concerns, you may contact Luke Foster at (918)444-5848 or Dr. Ernst Bekkering, IRB chairman at (918)444-2917.

Signatures: I have read and fully understand the consent form. I sign it freely and voluntarily. A copy of this form has been given to me.

________________________________ _____________

Signature of Participant Date

APPENDIX H

DEMOGRAPHIC SURVEY

1) Are you Male or Female?

Male Female

2) What is your age?

18-21 22-25 26-30 31-40 41-50 51-60 61 or over

3) What academic classification are you?

Freshman Sophomore Junior Senior Graduate

4) What is your current marital status?

Single Married Divorced

5) How many children do you have?

0 1 2 3 4 5 or more

6) What is your race?

White, Non-Hispanic African-American Hispanic

Asian-Pacific Islander Native American Other _____________

7) What is the highest level of education your mother has completed?

Less than High School High School/GED Some College

2-year College Degree 4-year College Degree Master's Degree

Doctoral Degree

8) What is the highest level of education your father has completed?

Less than High School High School/GED Some College

2-year College Degree 4-year College Degree Master's Degree

Doctoral Degree

APPENDIX I

LEARNING ACTIVITIES

INTRODUCTION TO GRAPHS

1. A list of presidents with the number of children for each follows.

1	Washington	0	**22**	Cleveland	5
2	J. Adams	5	**23**	B. Harrison	3
3	Jefferson	6	**24**	McKinley	2
4	Madison	0	**25**	T. Roosevelt	6
5	Monroe	2	**26**	Taft	3
6	J.Q. Adams	4	**27**	Wilson	3
7	Jackson	0	**28**	Harding	0
8	Van Buren	4	**29**	Coolidge	2
9	W.H. Harrison	10	**30**	Hoover	2
10	Tyler	14	**31**	F.D. Roosevelt	6
11	Polk	0	**32**	Truman	1
12	Taylor	6	**33**	Eisenhower	2
13	Fillmore	2	**34**	Kennedy	3
14	Pierce	3	**35**	L.B. Johnson	2
15	Buchanan	0	**36**	Nixon	2
16	Lincoln	4	**37**	Ford	4
17	A. Johnson	5	**38**	Carter	3
18	Grant	4	**39**	Reagan	4
19	Hayes	8	**40**	G. Bush	4
20	Garfield	7	**41**	Clinton	1
21	Arthur	3	**42**	G.W. Bush	2

a) Make a frequency distribution for this data

b) What is the most frequent number of children?

2. The grade distribution for the final examination for a mathematics course is shown.

Grade	Frequency
A	4
B	10
C	37
D	8
F	1

a) Draw a bar graph for this data.

b) Draw a circle graph for this data.

3. Make a pictograph to represent the data using ♥ to represent 10 boxes of valentines sold.

BOXES OF VALENTINES SOLD

DAY	TALLY
Monday	𝍸 𝍸 𝍸
Tuesday	𝍸 𝍸 𝍸 𝍸
Wednesday	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸
Thursday	𝍸 𝍸
Friday	𝍸

4. Two college roommates kept a record of last month's expenses as summarized in the table below.

ITEM	AMOUNT
Food	$180
Rent	$150
Clothing	$60
Books	$60
Entertainment	$90
Other	$60

Construct a graph that would be most applicable to illustrate this data.

5. The given data represent total car sales for Johnson's car lot from January through June. Draw an appropriate graph to illustrate this data.

MONTH	JAN	FEB	MAR	APR	MAY	JUN
No. of cars sold	90	86	92	98	90	100

6. The results of a mathematics methods test are presented below in the table. Organize this data and present it in an appropriate graph form.

52	56	25	56	68	73	66	64	56	100
20	39	09	50	98	54	54	40	50	96
36	44	18	97	100	65	21	60	44	54
92	49	37	94	72	88	89	35	59	34
48	32	15	53	84	72	88	16	52	60

FISH ACTIVITY

A fish farmer stocked a pond with a new type of genetically engineered fish. The company that supplied the new type claims that these fish will grow to be longer than normal fish. The farmer decided to test this claim by stocking the pond with 625 fish, some normal and some genetically engineered. When the fish were fully grown, the farmer caught some of the fish and measured them.

1. Open the TinkerPlots document **Fish.tp**. These are the 130 fish the farmer caught and measured.

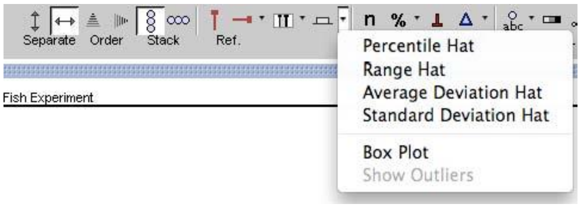
2. Use the plot to make a graph of the data that allows you to compare the lengths of the two groups of fish.

3. Sketch the graph you made.

4. Do the genetically engineered fish tend to grow longer than the normal fish? Support your conclusion by referring to your graph.

5. If you concluded that the genetically engineered fish do tend to grow longer, about how much longer than the normal fish do they tend to be? Support your conclusion by referring to your graph. (You may want to use the **Ruler** tool to help you answer this question.)

6. From the sample, does it appear that the genetically engineered fish are any more or less variable in length than the normal fish? Support your conclusion with data. (Hat plots may help in comparing variability. You can select different types of hat plots from the **Hat Options** menu.)



The sample of 130 fish was picked from a population of 625 fish. Based on that sample, you were asked to draw a conclusion about *al*l the fish, not just the sample of 130. A question you might be thinking when you make such an **inference** is, “What would I have concluded if a different random sample of 130 fish were picked? Is 130 fish a big enough sample to make a conclusion about all the fish?”

To explore that question, you will take more samples from the whole population of 625 fish and see how similar or different the samples are.

7. Open the TinkerPlots document **Fish Population.tp**.
   The 625 fish are in a mixer. The mixer is set to draw a sample of 200 fish. It is also set to sample without replacement—meaning that when a fish is selected, it is not put back into the mixer (pond) before the selection of another fish.
8. Change the sampler to select 130 fish. To do this, click the number beneath Repeat in the sampler and change it to 130. Click the **RUN** button to run the sampler.
9. Make a plot showing the lengths of the two types of fish. Then compare the averages for the two types of fish. (Select the plot and then click the **Mean** or **Median** button. When you hover over  or  (representing the mean or median), its exact value is shown in the lower left corner of the TinkerPlots window.) Would you have reached the same conclusion about the data from this sample of 130 fish as you did for the data from your last sample of 130 fish? Explain.
10. Draw several more random samples of 130 fish by clicking the **RUN** button on the sampler again. (You may want to speed up the sampler if you haven’t already.) Record similarities and differences you observe.

11. Suppose the farmer were to catch only 15 fish. Set Repeat to 15. Now run several random samples and record what you observe.
12. Is 15 fish a big enough sample to decide whether the genetic fish are longer than normal fish and how much longer they tend to be?
13. Usually, you cannot see the entire population from which a sample is drawn, but in this example you can. Set Repeat to 625 to "catch" all the fish. Sample them to see what the plot of all the fish looks like.
14. What is the average length for each group of fish? What is the difference between the averages of the two groups? How do the estimates you got from the various samples you took during this activity compare with the measures from the entire population?

Fish	Length	Type
147	28	genetic
625	28	genetic
259	38	genetic
225	28	genetic
108	26	normal
230	37	normal
576	28	genetic
319	21	genetic
617	40	normal
618	27	genetic
94	37	genetic
596	31	genetic
458	32	normal
519	27	genetic
464	22	genetic
452	27	genetic
573	19	genetic
292	23	normal
454	28	normal
260	23	normal
370	22	normal
578	32	normal
196	28	genetic
212	20	genetic
140	28	normal
373	39	genetic
304	14	normal
529	26	genetic
195	33	genetic
102	28	genetic
15	23	normal
269	22	normal
332	19	normal
507	23	normal
86	17	normal
187	13	genetic
293	23	normal
474	31	genetic
192	36	genetic
410	27	genetic
150	34	normal
545	29	genetic
58	26	normal

Fish	Length	Type
171	29	genetic
415	24	normal
553	24	genetic
467	12	normal
126	23	normal
178	23	normal
417	36	genetic
598	26	normal
228	29	genetic
374	17	genetic
585	26	normal
482	23	normal
325	22	normal
4	23	genetic
41	26	normal
523	19	normal
532	27	normal
43	32	genetic
264	14	normal
528	15	normal
96	24	normal
55	34	genetic
233	19	normal
224	36	normal
348	18	normal
349	32	genetic
346	22	genetic
144	25	normal
379	24	normal
79	28	normal
176	30	genetic
565	21	normal
586	32	genetic
132	27	normal
548	31	genetic
444	23	normal
510	26	genetic
568	19	normal
134	42	normal
441	26	normal
534	31	genetic
47	24	normal
540	17	normal
177	24	normal

Fish	Length	Type
336	18	normal
227	26	normal
504	23	normal
211	21	normal
396	29	normal
119	21	normal
142	26	normal
360	22	normal
2	27	normal
66	21	genetic
338	22	normal
359	31	normal
505	31	genetic
251	22	normal
557	22	normal
166	27	genetic
416	27	genetic
307	30	genetic
353	24	normal
277	16	normal
434	29	genetic
131	28	genetic
435	27	genetic
365	29	normal
610	33	genetic
28	28	genetic
324	21	normal
180	29	normal
201	25	normal
19	25	genetic
380	22	normal
222	22	genetic
561	23	genetic
137	31	normal
139	22	normal
387	25	genetic
621	18	normal
289	25	genetic
516	21	normal
1	38	genetic
389	23	normal
106	22	normal
388	21	normal

YO-YO ACTIVITY

Last night, the Yo-Yo Factory was broken into and robbed. Detectives investigating the break-in think that it was an "inside job." Their prime suspect has been working at the Yo-Yo Factory for six months. The police want you to look at some data that could help solve the mystery. Before you look at the data, you need to know some of the facts of the case.

Information from the Police Report

The Yo-Yo Factory makes yo-yos. The plastic bodies of their yo-yos are made by a machine that can make about 147,600 yo-yo bodies each day. The machine runs 24 hours a day.

Yesterday evening, the last person to leave the Yo-Yo Factory was the manager. He left at 8:00 P.M. He was also the first person to arrive in the morning, at 6:00 A.M. When he got there, he discovered the front door had been forced open. He also found that the company's safe had been broken into. About $4,500 was missing.

Every two minutes, the yo-yo machine automatically records the number of yo-yo bodies it has made during the last two minutes. The number of yo-yos it makes every two minutes varies, but on average it makes about 210 yo-yos.

The front door was forced open during last night's break-in. When that happened, all the power went off just for a moment, and then it came back on. When the power goes out, even for a moment, the yo-yo machine slows down a little. It then keeps working at this slower speed until someone who knows how readjusts it. This means that for the rest of the night after the break-in, the machine was running at this slower speed, making fewer yo-yos on average than it normally does.

The police hope that by looking at the data from the yo-yo machine, you will be able to tell them when the break-in happened. What they most want to know is whether the break-in happened before 12:00 A.M. or after 3:00 A.M., because these are times when their suspect has no alibi.

The suspect told police that last night he went home right after work at 5:30 P.M., ate, and then slept for a while. He lives alone, so no one can back up his story. He was at a club with friends from 12:00 A.M. to 3:00 A.M. People at the club saw him there during those times. He says he was home alone sleeping from 3:30 A.M. to 7:00 A.M.

The police made this chart to show what they know so far:

Time	Event at Factory	Suspect's Location
8:00 P.M.	Manager last to leave	?
9:00 P.M.		?
10:00 P.M.		?
11:00 P.M.		?
12:00 A.M.		Arrives at club
1:00 A.M.		At club
2:00 A.M.		At club
3:00 A.M.		Leaves club
4:00 A.M.		?
5:00 A.M.		?
6:00 A.M.	Manager discovers break-in	?

Plot and Investigate

Now you'll look at the data to see what they say.

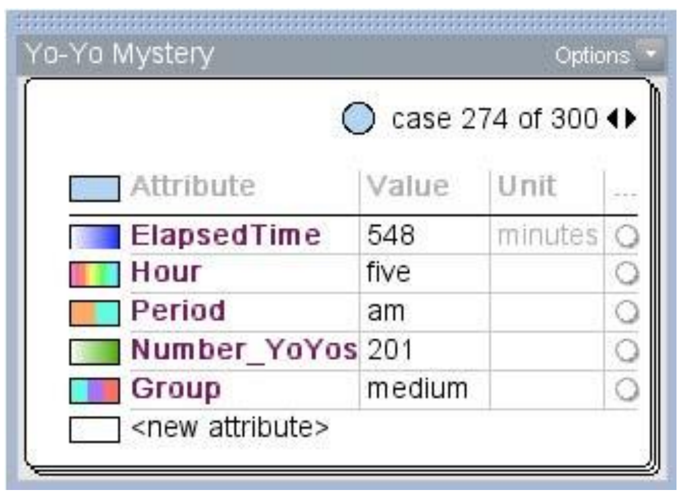
1 Open the document **Yo-Yo Mystery.tp.** You'll see a stack of data cards like the one at right. The attribute names are described below the data cards. Read the descriptions so that you know what the attribute names mean.

2. The data card at right shows the data for case 274.

   a. Explain what the value of 201 for *Number_YoYos* means.

   b. Explain what the value of "five" for *Hour* means.

   c. Explain what the value of 548 for *ElapsedTime* means.



3. Make a graph that helps you decide when the break-in probably happened. Include a copy of your graph with your assignment.

4. Looking at the data, about when do you think the break-in happened? Explain how your graph backs up your conclusion.

5. Based on your graph, could the suspect have committed the break-in? Explain.

Hour	Time	Period	YoYos	Group
2	eight	pm	209	medium
4	eight	pm	186	medium
6	eight	pm	159	low
8	eight	pm	223	medium
10	eight	pm	246	high
12	eight	pm	196	medium
14	eight	pm	233	high
16	eight	pm	205	medium
18	eight	pm	212	medium
20	eight	pm	211	medium
22	eight	pm	245	high
24	eight	pm	220	medium
26	eight	pm	259	high
28	eight	pm	218	medium
30	eight	pm	200	medium
32	eight	pm	181	low
34	eight	pm	200	medium
36	eight	pm	205	medium
38	eight	pm	224	medium
40	eight	pm	233	high
42	eight	pm	221	medium
44	eight	pm	211	medium
46	eight	pm	213	medium
48	eight	pm	238	high
50	eight	pm	214	medium
52	eight	pm	205	medium
54	eight	pm	213	medium
56	eight	pm	244	high
58	eight	pm	199	medium
60	eight	pm	220	medium
62	nine	pm	183	medium
64	nine	pm	190	medium
66	nine	pm	207	medium
68	nine	pm	177	low
70	nine	pm	194	medium
72	nine	pm	196	medium
74	nine	pm	217	medium
76	nine	pm	259	high
78	nine	pm	239	high
80	nine	pm	229	high
82	nine	pm	243	high
84	nine	pm	200	medium
86	nine	pm	173	low
88	nine	pm	163	low
90	nine	pm	203	medium
92	nine	pm	240	high
94	nine	pm	213	medium
96	nine	pm	210	medium
98	nine	pm	204	medium
100	nine	pm	196	medium
102	nine	pm	207	medium
104	nine	pm	217	medium
106	nine	pm	235	high
108	nine	pm	241	high
110	nine	pm	191	medium
112	nine	pm	202	medium
114	nine	pm	220	medium
116	nine	pm	194	medium
118	nine	pm	209	medium
120	nine	pm	210	medium
122	ten	pm	200	medium
124	ten	pm	217	medium
126	ten	pm	218	medium
128	ten	pm	192	medium
130	ten	pm	158	low
132	ten	pm	173	low
134	ten	pm	215	medium
136	ten	pm	190	medium
138	ten	pm	217	medium
140	ten	pm	211	medium
142	ten	pm	239	high
144	ten	pm	257	high
146	ten	pm	205	medium
148	ten	pm	232	high
150	ten	pm	244	high
152	ten	pm	236	high
154	ten	pm	172	low
156	ten	pm	195	medium
158	ten	pm	232	high
160	ten	pm	237	high
162	ten	pm	200	medium
164	ten	pm	253	high
166	ten	pm	213	medium
168	ten	pm	211	medium
170	ten	pm	232	high
172	ten	pm	236	high
174	ten	pm	222	medium
176	ten	pm	216	medium
178	ten	pm	202	medium
180	ten	pm	203	medium

Hour	Time	Period	YoYos	Group
182	eleven	pm	208	medium
184	eleven	pm	175	low
186	eleven	pm	238	high
188	eleven	pm	207	medium
190	eleven	pm	244	high
192	eleven	pm	226	medium
194	eleven	pm	239	high
196	eleven	pm	176	low
198	eleven	pm	245	high
200	eleven	pm	190	medium
202	eleven	pm	206	medium
204	eleven	pm	231	high
206	eleven	pm	206	medium
208	eleven	pm	195	medium
210	eleven	pm	210	medium
212	eleven	pm	199	medium
214	eleven	pm	208	medium
216	eleven	pm	209	medium
218	eleven	pm	231	high
220	eleven	pm	231	high
222	eleven	pm	193	medium
224	eleven	pm	215	medium
226	eleven	pm	201	medium
228	eleven	pm	184	medium
230	eleven	pm	206	medium
232	eleven	pm	247	high
234	eleven	pm	239	high
236	eleven	pm	207	medium
238	eleven	pm	198	medium
240	eleven	pm	215	medium
242	twelve	am	190	medium
244	twelve	am	195	medium
246	twelve	am	210	medium
248	twelve	am	242	high
250	twelve	am	233	high
252	twelve	am	214	medium
254	twelve	am	227	medium
256	twelve	am	218	medium
258	twelve	am	235	high
260	twelve	am	182	low
262	twelve	am	236	high
264	twelve	am	205	medium
266	twelve	am	193	medium
268	twelve	am	197	medium
270	twelve	am	202	medium

Hour	Time	Period	YoYos	Group
272	twelve	am	208	medium
274	twelve	am	178	low
276	twelve	am	172	low
278	twelve	am	193	medium
280	twelve	am	230	high
282	twelve	am	184	medium
284	twelve	am	189	medium
286	twelve	am	238	high
288	twelve	am	204	medium
290	twelve	am	174	low
292	twelve	am	207	medium
294	twelve	am	213	medium
296	twelve	am	209	medium
298	twelve	am	213	medium
300	twelve	am	241	high
302	one	am	239	high
304	one	am	193	medium
306	one	am	211	medium
308	one	am	215	medium
310	one	am	194	medium
312	one	am	212	medium
314	one	am	174	low
316	one	am	203	medium
318	one	am	201	medium
320	one	am	226	medium
322	one	am	230	high
324	one	am	183	medium
326	one	am	258	high
328	one	am	226	medium
330	one	am	174	low
332	one	am	221	medium
334	one	am	202	medium
336	one	am	199	medium
338	one	am	217	medium
340	one	am	209	medium
342	one	am	208	medium
344	one	am	246	high
346	one	am	216	medium
348	one	am	186	medium
350	one	am	272	high
352	one	am	206	medium
354	one	am	215	medium
356	one	am	202	medium
358	one	am	178	low
360	one	am	247	high

Hour	Time	Period	YoYos	Group
362	two	am	216	medium
364	two	am	207	medium
366	two	am	226	medium
368	two	am	247	high
370	two	am	238	high
372	two	am	227	medium
374	two	am	217	medium
376	two	am	223	medium
378	two	am	220	medium
380	two	am	197	medium
382	two	am	208	medium
384	two	am	179	low
386	two	am	213	medium
388	two	am	186	medium
390	two	am	210	medium
392	two	am	196	medium
394	two	am	179	low
396	two	am	194	medium
398	two	am	204	medium
400	two	am	185	medium
402	two	am	217	medium
404	two	am	215	medium
406	two	am	195	medium
408	two	am	219	medium
410	two	am	170	low
412	two	am	168	low
414	two	am	223	medium
416	two	am	202	medium
418	two	am	182	low
420	two	am	212	medium
422	three	am	187	medium
424	three	am	172	low
426	three	am	173	low
428	three	am	188	medium
430	three	am	202	medium
432	three	am	224	medium
434	three	am	177	low
436	three	am	215	medium
438	three	am	197	medium
440	three	am	195	medium
442	three	am	198	medium
444	three	am	180	low
446	three	am	145	low
448	three	am	197	medium
450	three	am	198	medium
452	three	am	190	medium
454	three	am	245	high
456	three	am	215	medium
458	three	am	256	high
460	three	am	184	medium
462	three	am	207	medium
464	three	am	149	low
466	three	am	165	low
468	three	am	190	medium
470	three	am	209	medium
472	three	am	202	medium
474	three	am	159	low
476	three	am	175	low
478	three	am	220	medium
480	three	am	180	low
482	four	am	199	medium
484	four	am	186	medium
486	four	am	204	medium
488	four	am	195	medium
490	four	am	223	medium
492	four	am	170	low
494	four	am	193	medium
496	four	am	154	low
498	four	am	204	medium
500	four	am	176	low
502	four	am	142	low
504	four	am	180	low
506	four	am	159	low
508	four	am	162	low
510	four	am	193	medium
512	four	am	167	low
514	four	am	221	medium
516	four	am	177	low
518	four	am	186	medium
520	four	am	194	medium
522	four	am	150	low
524	four	am	198	medium
526	four	am	170	low
528	four	am	172	low
530	four	am	200	medium
532	four	am	185	medium
534	four	am	176	low
536	four	am	186	medium
538	four	am	202	medium
540	four	am	176	low

Hour	Time	Period	YoYos	Group
542	five	am	183	medium
544	five	am	174	low
546	five	am	150	low
548	five	am	201	medium
550	five	am	182	low
552	five	am	188	medium
554	five	am	157	low
556	five	am	206	medium
558	five	am	148	low
560	five	am	192	medium
562	five	am	216	medium
564	five	am	179	low
566	five	am	174	low
568	five	am	176	low
570	five	am	199	medium

Hour	Time	Period	YoYos	Group
572	five	am	183	medium
574	five	am	190	medium
576	five	am	181	low
578	five	am	187	medium
580	five	am	199	medium
582	five	am	206	medium
584	five	am	181	low
586	five	am	164	low
588	five	am	164	low
590	five	am	188	medium
592	five	am	200	medium
594	five	am	197	medium
596	five	am	207	medium
598	five	am	213	medium
600	five	am	207	medium

BACKPACK ACTIVITY

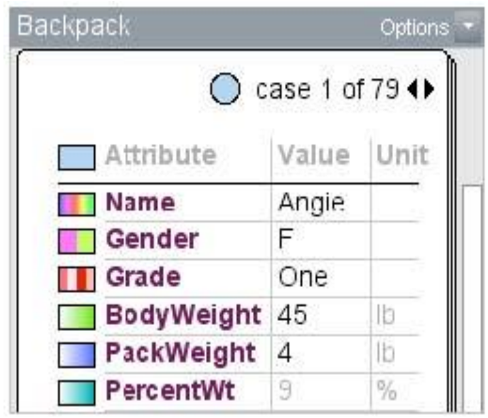
Is Your Backpack Too Heavy for You?

Many students develop back problems. Doctors believe that these problems are caused by the heavy backpacks students carry. Sometimes the way students carry their backpacks also hurts their backs.

In this activity you'll decide which students are carrying backpacks that are too heavy.

The data you'll look at were collected by students. They went to one classroom in each grade at a school and had students weigh themselves and their backpacks.

At right is the data for Angie, a girl in first grade. The card shows that she weighs 45 pounds and her backpack weighs 4 pounds. (The "lb" you see in the **Unit** column is the abbreviation for pounds.)



Think About It

Before you look at data, think about what you expect to see. You probably already have some ideas about what these data look like.

1 About how heavy can a student's backpack safely be? (If you can, discuss this with a partner.)

2 Do you think that some students can safely carry heavier backpacks than other students? Explain.

3. Doctors recommend that a student's backpack should weigh no more than 15% of his or her body weight.

   a. What is the heaviest safe backpack weight for a student who weighs 100 pounds?
   ________ pounds

   b. What is the heaviest safe backpack weight for a student who weighs 150 pounds?
   ________ pounds

Plot and Investigate

Now you'll look at the data to see what they say.

1 Open the document **Too Heavy Backpacks.tp.** You should see a plot and a stack of data cards like the one on the previous page. Look at the attribute on the bottom row of the data cards. This attribute is named *PercentWt*. It tells you what percentage a student's backpack weight is of his or her body weight.

2 First you'll look at which students carry backpacks that are too heavy. Make a graph that lets you quickly find these students. (*Hint*: To make your graph and answer the next question, you might use reference lines, dividers, or the percent button. These features are on the upper plot toolbar.)

3 About what percentage of the students carry backpacks that are too heavy (more than 15% of their body weight)?

Students in the higher grades (grades 5 and 7) carry heavier backpacks than students in the lower grades. But students in higher grades also tend to weigh more than students in lower grades. What do you find if you look at percent weight? Find out if students in the higher grades carry heavier backpacks for their body weight than students in the lower grades.

7. Make a graph that helps you see whether students in the higher grades carry heavier backpacks for their body weight than students in lower grades. Include a copy of your graph with your assignment.

8. What percentage of students in the higher grades (grades 5 and 7) carry backpacks that are too heavy (more than 15% of their body weight)?

9. What percentage of students in the lower grades (grades 1 and 3) carry backpacks that are too heavy?

10. Which students tend to carry backpacks that weigh more for their body weight— students in higher grades or students in lower grades? Explain. Your answer should say how your graph backs up your conclusion. Also include any other conclusions you can make from your graph and explain how your graph supports them.

Name	Gender	Grade	BodyWeight	PackWeight	PercentWt
Angie	F	One	45	4	9
Emma	F	One	46	4	9
Sadie	F	One	32	3	9
Maddyn	F	One	47	3	6
Lorien	F	One	60	7	12
Bailey	F	One	52	6	12
Micah	F	One	57	6	11
Kilie	F	One	48	10	21
Abigail	F	One	46	3	7
Eugene	M	One	34	3	9
Leroy	M	One	61	5	8
Jim	M	One	44	4	9
Ross	M	One	49	3	6
Grennan	M	One	53	10	19
Finley	M	One	48	5	10
Jackson	M	One	46	5	11
Wesley	M	One	35	3	9
Elly	F	Three	56	7	13
Isable	F	Three	59	4	7
Haley	F	Three	51	7	14
Kayleen	F	Three	51	6	12
Alysaa	F	Three	62	7	11
Riley	F	Three	46	4	9
Rachel	F	Three	72	5	7
Alison	F	Three	62	11	18
Erin	F	Three	84	5	6
Kristen	F	Three	59	8	14
Wendy	F	Three	54	8	15
Bryant	M	Three	60	5	8
Trevor	M	Three	58	6	10
Karsten	M	Three	63	7	11
Anthony	M	Three	59	6	10
Greg	M	Three	56	7	13
Josh	M	Three	53	7	13
Todd	M	Three	73	7	10
Michael	M	Three	51	9	18
Byron	M	Three	44	7	16
Dan	M	Three	84	4	5
Brandy	F	Five	53	10	19
Wendie	F	Five	66	5	8
Chessa	F	Five	73	7	10
Merinda	F	Five	76	19	25
Mimi	F	Five	76	14	18

Name	Gender	Grade	BodyWeight	PackWeight	PercentWt
Kelly	F	Five	78	13	17
Cameron	F	Five	81	3	4
Darice	F	Five	93	17	18
Heather	F	Five	108	12	11
Larry	M	Five	60	8	13
Tanner	M	Five	64	15	23
Quinn	M	Five	68	11	16
Tyson	M	Five	68	22	32
Darrly	M	Five	72	6	8
Ryan	M	Five	73	14	19
Brad	M	Five	75	12	16
Matt	M	Five	75	9	12
Chris	M	Five	80	11	14
Keith	M	Five	82	21	26
Lenn	M	Five	96	9	9
Nathan	M	Five	113	7	6
Megan	F	Five	96	8	8
Katie	F	Seven	87	21	24
Deborah	F	Seven	94	5	5
Jennifer	F	Seven	78	14	18
Lori	F	Seven	82	12	15
Sherry	F	Seven	72	9	13
Kathy	F	Seven	114	22	19
Pat	F	Seven	98	19	19
Gayle	F	Seven	107	39	36
Myrle	F	Seven	120	20	17
Jeffrey	M	Seven	104	27	26
Alan	M	Seven	79	19	24
Paul	M	Seven	95	19	20
Chad	M	Seven	84	3	4
Ken	M	Seven	98	16	16
Phil	M	Seven	111	19	17
Warren	M	Seven	76	16	21
Tim	M	Seven	90	9	10
Steve	M	Seven	119	21	18
William	M	Seven	70	21	30

APPENDIX J

COURSE SYLLABUS

Northeastern State University
College of Math, Science, and Nursing
Department of Mathematics
Tahlequah, OK

INSTRUCTOR:
Luke Foster, Instructor Office: SS LL050
Office Hours: 10:00 – 11:00 MWF, 8:30 – 9:30 TT or by appointment
Telephone: 918-444-5848
FAX: 918-458-2325
E-mail: fosterlb@nsuok.edu
Web site: < http://arapaho.nsuok.edu/~fosterlb>

COURSE TITLE AND NUMBER:
MATH 3443 – Modeling: Real Numbers and Statistics

CLASS DAY & TIME:
9:30 – 10:45 TT

PREREQUISITES:
Math 1473 or Math 1513.

CATALOG DESCRIPTION OF COURSE:
A study of mathematical concepts for the elementary education major using tactile models and appropriate technology. Topics include: Rational numbers and their operations, integers and their operations, and statistics and probability. No major or minor credit in mathematics.

COURSE PURPOSE:
The Teacher Education Program at Northeastern State University prepares professional educators to be **teaching scholars, educational leaders, and developers of human potential**.

Educators as Teaching Scholars
Teaching scholars read widely and think deeply about subject matter, teaching, and research. They reflect critically on their own beliefs and their classroom practice in order to make pedagogical improvements. Teaching scholars use appropriate communication skills, they know how to facilitate authentic learning, and they encourage P-12 students to be critical, creative thinkers, with the ability to be lifelong learners.

Educators as Educational Leaders
Educational leaders believe that all P-12 students are capable of learning and of making educational progress. Educational leaders serve as advocates for children/adolescents and families, they understand the political nature of teaching, and they are able to inspire and motivate others by modeling effective communication skills, professional demeanor and attitudes.

Educators as Developers of Human Potential
Educators who are developers of human potential are committed to the philosophical position that the development of human potential is their fundamental task.

STUDENT LEARNING OUTCOMES:
The successful student should:

1. have a well-developed rational number sense, including estimation, mental mathematics, and reasonableness of results.
2. be knowledgeable of the use of rational number concepts, operations on rational numbers, and properties of the four basic operations on rational numbers.
3. be knowledgeable of the role of and be able to explain and illustrate with models each of the four basic operations on rational numbers.
4. be knowledgeable of the role of and be able to explain and illustrate with models the algorithms of each of the four basic operations on rational numbers.
5. have a well-developed integer number sense, including estimation, mental mathematics, and reasonableness of results.
6. be knowledgeable of the use of integer concepts, operations on integers, and properties of the four basic operations on integers.
7. be knowledgeable of the role of and be able to explain and illustrate with models each of the four basic operations on integers.
8. be knowledgeable of the role of and be able to explain and illustrate with models the algorithms of each of the four basic operations on integers.
9. be knowledgeable of the collection, organization, representation, analysis, and interpretation of data.
10. be knowledgeable of the probability of simple and compound events.
11. be knowledgeable of the misconceptions of probability.
12. be knowledgeable of the organization of data for the purpose of communication with others.
13. be knowledgeable of the potential misuses of statistics.
14. be knowledgeable of the use of the statistical concepts of dispersion and central tendency

INSTRUCTIONAL MATERIALS:

The following is a list of materials that will be used during the course to develop proficiency in modeling elementary mathematical concepts. This is not intended to be an exhaustive list, but a representative list of the materials. Additional materials may be used as the need arises.

Fraction Strips	Fraction Circles	Pattern Blocks
Base Ten Blocks	Colored Cubes	Two Colored Chips
Geoboards	Mirrors	Protractors
Rulers	Compasses	Computers

INSTRUCTIONAL PROCEDURES:
The expected course outcomes will be realized through a variety of instructional strategies. Those strategies include, but are not limited to, the following: expository-discussion,

demonstration, inquiry, and group activities. The instructor also will integrate appropriate multi-media technology and utilize appropriate models for mathematics concepts for the purpose of enriching the students total experience.

STUDENT PERFORMANCE ACTIVITIES: *(Attendance/Punctuality)*
Consistent and punctual attendance is both expected and required for your successful completion of the course. Students will not be allowed to make up any missed class work. Excessive absences may reduce the final grade for the course.

ASSIGNMENT DUE DATES:
Assignments are due at the beginning of the class period following the date when the assignment is given, unless otherwise noted by the instructor. The student is responsible for all material assigned even if not discussed in class.

EVALUATION OF STUDENT ACHIEVEMENT AND LEARNING OUTCOMES:
There will be three written tests scheduled during the semester. Each test will count 18%. These tests will be of varying design with objective questions, short answer questions, and some problems. There will be a comprehensive final worth 28%. There will also be a laboratory assessment. This will be an individual performance evaluation that will be scheduled later during the semester. Each student must pass the individual performance evaluation to pass the course. In-class assignments and homework are also worth 18%.

The grading scale will be as follows:

90 % to 100% = A
80% to 89% = B
70% to 79% = C
60% to 69% = D
0% to 59% = F

Students are advised that the last date during the semester when they may drop a course with an automatic "W" will be April 8, 2012. If you decide to drop after this date, you will receive the grade you have earned up to the drop date. The grade of "W" will be assigned if your grade is a "D" or higher; and an "F" will be assigned if you stop attending and have not turned in assignments or have not taken scheduled exams prior to the drop date.

ADDIONAL INFORMATION:
Please go to http://offices.nsuok.edu/academicaffairs/SyllabiInformation.aspx for required information pertaining to:

1. Academic Misconduct
2. American Disabilities Act Compliance
3. Inclement Weather/Disaster Policy
4. Teach Act
5. Accessibility
6. Release of Confidential Information

APPENDIX K

WORD CLOUD GENERATED BY *WORDLE*

APPENDIX K

IRB APPROVALS

Oklahoma State University Institutional Review Board

Date:	Friday, September 28, 2012
IRB Application No	ED12150
Proposal Title:	Impact of Tinkerplots on Preservice Elementary Teachers' Understanding of Measures of Center and Graphical Representations-II
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved Protocol Expires: 9/27/2013

Principal Investigator(s):

Luke Foster
902 Owens Ave.
Tahlequah, OK 74464

Juliana Utley
233 Willard
Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☒ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI, advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Beth McTernan in 219 Cordell North (phone: 405-744-5700, beth.mcternan@okstate.edu).

Sincerely,

Shelia M. Kennison

Shelia Kennison, Chair
Institutional Review Board

Human Subjects Review
Proposal Title: Impact of Tinkerplots on Preservice Elementary Teachers' understanding of measures of center and graphical representations
IRB #: 12-207

Dear Mr. Foster

Your research proposal has been approved by the Institutional Review Board at Northeastern State University. It is the IRB's opinion that you have provided adequate safeguards for the welfare of the participants in this study.

You are authorized to begin your research and implement this study as of 8/23/12. This authorization is valid until 8/22/13. After this authorization runs out, you are required to submit a continuation or renewal request for board approval. If you would like to receive this permission on IRB letterhead, please send a self-addressed stamped envelope or email me where you would like to have an interoffice mail envelope sent.

This approval is granted with the understanding that the research will be conducted within the published guidelines of the NSU Institutional Review Board and as described in your application. Any changes or modifications to the approved protocols should be submitted to the IRB for approval if they could affect the safety, rights, and welfare of the participants in your study. Please use the IRB number in all your communications.
Thank you for sending us your application for research involving human subjects. In doing so, you safeguard the welfare of participants in your study and federal funding of our university.

Signed: ___Ernst Bekkering, Ph.D.______
Ernst Bekkering
Chair, Institutional Review Board

VITA

Luke Burton Foster

Candidate for the Degree of

Doctor of Philosophy

Dissertation: IMPACT OF *TINKERPLOTS*™ ON PRESERVICE ELEMENTARY TEACHERS' UNDERSTANDING OF MEASURES OF CENTER AND GRAPHICAL REPRESENTATIONS

Major Field: Professional Education/Mathematics Education

Education: Completed the requirements for the Doctor of Philosophy in Professional Education with an Emphasis in Mathematics Education at Oklahoma State University, Stillwater, Oklahoma in July 2013.

Master of Science in Applied Mathematics, Oklahoma State University, Stillwater, Oklahoma, May 1996.

Bachelor of Science in Mathematics Education, Northeastern State University, Tahlequah, Oklahoma, May 1992.

Experience:

1997 – Present Instructor of Mathematics, Department of Mathematics and Computer Science, Northeastern State University, Tahlequah, Oklahoma.
Courses taught: Beginning Algebra, Intermediate Algebra, College Algebra, Applied Mathematics, Calculus III, Linear Algebra, Statistical Methods, Mathematical Statistics, Data Analysis, Technology in Mathematics, Modeling: Geometry and Measurement, Modeling: Numeration and Operation, Modeling: Real Numbers and Statistics

1995 – 1997 Instructor/Assistant Professor of Mathematics, Owensboro Community College, Owensboro, Kentucky
Courses taught: Beginning Algebra, Intermediate Algebra, College Algebra, Applied Mathematics, Calculus I

Professional Memberships:

Member, Research Council on Mathematics Learning
Member, National Council of Teachers of Mathematics

ABSTRACT

Name: Luke Foster Date of Degree: July, 2013

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: IMPACT OF *TINKERPLOTS*™ ON PRESERVICE ELEMENTARY TEACHERS' UNDERSTANDING OF MEASURES OF CENTER AND GRAPHICAL REPRESENTATIONS

Pages in Study: 129 Candidate for the Degree of Doctor of Philosophy

Major Field: Professional Education/Mathematics Education

Scope and Method of Study:

This concurrent embedded mixed methods study investigates the influence of the computer program *Tinkerplots*™ on 34 preservice elementary teachers' understanding of measures of center and graphical representations of data. Participants' opinions and beliefs about the effectiveness of the program were also explored.

Findings and Conclusions:

At the beginning of the experimental period, participants had marginal understanding of measures of center and graphical representations. Both the control and experimental groups showed an improved understanding at the end of the experimental period. It is still unclear what influence *Tinkerplots*™ had on the understanding of participants in the experimental group, since quantitative analysis revealed that the experimental group did not perform significantly better than the control group. However, this does not diminish the fact that pre-service elementary teachers need to be statistically literate, and if certain educational tools can enhance their statistical understanding, then utilizing those tools is beneficial. This research study did provide some evidence, through participant responses on multiple instruments, that one such tool, *Tinkerplots*™, can be effective in enhancing the statistical learning experience for pre-service elementary teachers. The fact that pre-service teachers believe that the program is effectual, regardless of quantitative analysis to reinforce the belief, can do nothing but encourage educators as to the potential learning experience offered by this type of program. It should be noted that although the analysis of the quantitative data doesn't support a claim of significant influence regarding *Tinkerplots*™, it also does nothing to discourage further research and investigation into this area of statistics education.

ADVISOR'S APPROVAL: ____