THE EFFECT OF USING MEASUREMENT BENCHMARKS ON THE BELIEFS AND METRIC KNOWLEDGE OF PRESERVICE ELEMENTARY TEACHERS

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The Effect of Using Measurement Benchmarks on the Beliefs and Metric Knowledge of Preservice Elementary Teachers

A Field Study

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The College of Graduate Studies

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In Partial Fulfillment

Of the Requirements for the Degree of

Educational Specialist in

Secondary Education

Audrey Bullock

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To the College of Graduate Studies:

We are submitting a field study written by Audrey Bullock entitled "The Effect of Using Measurement Benchmarks on the Beliefs and Metric Knowledge of Preservice Elementary Teachers." We have examined the final copy of this field study for form and content. We recommend that it be accepted in partial fulfillment of the requirements for the degree of Educational Specialist.

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DEDICATION

I would like to dedicate this study to all of my family members and friends that have supported me throughout this process. Special thanks go to my husband Caleb and daughter Annabelle who have watched me spend hours on this study and have encouraged me along the way. I appreciate your patience and support, and want to express my gratitude towards the many ways in which you each have made this work possible.

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ABSTRACT

AUDREY NICOLE BULLOCK. The Effect of Using Measurement Benchmarks on the Beliefs and Metric Knowledge of Preservice Elementary Teachers (under the direction of DR. JOHN MCCONNELL III).

The purpose of this study was to determine if there were differences in knowledge of or beliefs towards the metric system between students who experienced either instruction using personal benchmarks or a more traditional approach. Two sections of a mathematics content course for undergraduate preservice elementary teachers were provided instruction focusing on either personal benchmarks or a more traditional approach concentrating on the meanings of the prefixes commonly used in the metric system. The 23 participants took both a pre and posttest designed to measure 1) knowledge of the metric system and 2) beliefs towards the metric system. Analyses of covariance revealed no statistically significant differences in metric system knowledge or beliefs towards the metric system between the two groups after controlling for preexisting knowledge and beliefs; however, a statistically significant increase in positive dispositions towards the metric system was observed for all participants regardless of type of instruction.

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CHAPTER I

Introduction

Statement of the Problem

Recent assessments of the mathematical knowledge of students indicate that there exists a particular weakness in the domain of measurement as compared to other areas such as algebra and data analysis (National Center for Educational Statistics, 2013). One particular area that students struggle to grasp is knowledge of the metric system. Both students and teachers in the United States are sometimes unfamiliar with the metric system of measurement that the rest of the world uses regularly. A solid knowledge of the metric system is crucial for students who will have careers in science, mathematics, medicine, government, or other fields with possible international ties. In order to address this unfamiliarity with the metric system, elementary teachers of science and mathematics must know how to best teach it to their students and be familiar with the strengths and reasonableness of the system as a whole. Students cannot be expected to develop a deep understanding of and appreciation for the metric system until their teachers do so.

Purpose of the Study

The current study seeks to address this problem by investigating a particular instructional strategy recommended in recent literature called *measurement benchmarks*, or *personal referents* (Joram, 2003; Joram, Gabriele, Bertheau, Gelman, & Subrahmanyam, 2005; Sowder, Sowder, & Nickerson, 2010). Measurement benchmarks are familiar items with known measurements that are used to make sense of a unit's general size. For example, Joram and colleagues (2005) reference using the length of a paperclip to roughly represent the length of one inch. For this study, the measurement benchmark strategy was used with a group of preservice elementary teachers. The results of the study provide information on the usefulness of using measurement benchmarks as an instructional strategy when teaching the metric system.

The purpose of the current study was to investigate the effect of using measurement benchmarks on the beliefs and metric knowledge of preservice elementary teachers in a mathematics content course at a four-year college in the southeastern United States. The independent variable in this study had two levels: 1) using measurement benchmarks as an instructional strategy and 2) using non-contextual drawings as an instructional strategy. Two sections of a mathematics content course experienced two different types of instruction meant to teach various concepts relating to the metric system. One group of preservice teachers developed measurement benchmarks for several metric units of length, area, and volume and used these benchmarks to aid with estimation and making sense of conversions. The second group of preservice teachers experienced very similar instruction with only one planned variation. Instead of associating the metric units with familiar everyday items, the group studied the meanings of common metric prefixes in relation to number line drawings. Twenty-three preservice teachers participated in the study and took a pre and postsurvey measuring their beliefs about the metric system and their ability to estimate measurements, complete unit conversions, and determine the reasonableness of given estimates, all factors suggested by the reviewed literature to be components of metric system knowledge.

The 2005 study by Joram et al. investigated similar variables with a population of third-grade students in an urban school in the United States. These researchers found that students who used the reference-point strategy, also termed measurement benchmark strategy, performed significantly better on estimation accuracy tasks and drawing accurate representations of standard units. Standard units are units that are consistent among locations and contexts. For example, the length of a marker would not be a standard unit because it could vary greatly. The length of one inch is standard because it has a consistent measure no matter who is using it or where it is being used.

Significance of the Study

The current study expanded the existing knowledge of using the measurement benchmark strategy with a different population, preservice elementary teachers who will ultimately be responsible for teaching measurement. The current study also used the metric system and units of area and volume, while the referenced study focused only on feet and inches. In addition, the current study also sought to investigate whether the measurement benchmarks strategy has any effect on the perspectives preservice teachers hold about the metric system. Primary and secondary teachers in mathematics and science may find the results of this study useful in improving their instruction. In addition, postsecondary educators of mathematics and science content and methods courses are interested in the best methods of teaching to share with their prospective teachers. Likewise, employers who train individuals unfamiliar with the metric system may find the results of the current study useful. By focusing on the metric system, this study is relevant to what the majority of students will need to know for their future endeavors.

Research Questions

1. What is the effect of using personal benchmarks while teaching elementary mathematics content on preservice teachers' knowledge of the metric system?

2. What is the effect of using personal benchmarks while teaching elementary mathematics content on the attitudes of preservice teachers towards the metric system?

Hypotheses

1. The metric system knowledge of preservice teachers who are taught personal benchmarks as part of instruction is significantly different than the knowledge of those who experience more traditional instruction.
2. The attitudes of preservice teachers who are taught personal benchmarks as part of instruction are significantly different than the attitudes of those who experience more traditional instruction.

Limitations

Certain limitations were anticipated in conducting this study. One severe limitation is that the available sample was one of convenience and was limited in size. These two aspects of the sample limit the generalizability of the findings and present a threat to external validity. This study did not represent a true experiment in that the two sections of the course were predetermined, so random assignment of individuals was not be feasible; however, the choice of which section received benchmark instruction was random. In addition, the time period between the pre and postsurveys was one month, which may not have been enough time for meaningful change in knowledge or beliefs to occur.

Because very similar items were used on the pre and post assessments to avoid a threat to validity due to using different testing instruments, a threat to validity exists because of repeated testing within a month of the preassessment. Additional limitations include that some students in both sections were absent for part of the instruction during the timing of the study, and this could have affected any gains they may have experienced in knowledge or beliefs due to the activities and discussions that took place in the classroom.

Assumptions

In planning this study, an assumption was made that many preservice teachers would have already had experiences with the metric system before entering the mathematics content course used in this study. Because of this assumption and the lack of random assignment, preexisting knowledge and beliefs were considered as covariates in the statistical design. It was also assumed that some preservice teachers would choose to use strategies they already knew to estimate and convert measurements. In addition, the researcher assumed that all preservice teachers were not proficient at measurement tasks such as those assessed when entering the chosen mathematics content course, and thus had room to improve. The study also assumed that participants would answer truthfully and to the best of their ability on the survey in regards to their beliefs about the metric system and basic knowledge of the metric system. Finally, it was assumed that there would not be diffusion of the effects between the two groups of participants as to create an additional threat to internal validity. This assumption appeared to hold true.

Definition of Terms

The following terms are defined to clarify their meaning and significance to this study:

Beliefs towards the metric system refer to the degree to which participants in the study think the metric system is important to know and teach, is useful and logical, and should be promoted by various community entities such as schools, government, and businesses.

Metric system knowledge for this study refers to the degree to which participants are able to convert metric measures, estimate the size of various items in given metric units, and determine if a given estimate of a standard object's size is reasonable or unreasonable.

Personal benchmarks are defined as a set of personally meaningful items that can be associated with standard units of measurement to aide in remembering the relative size of that unit. For example, the thickness of a dime is about 1 mm, so the thickness of a dime could be a personal benchmark for remembering the length of 1 mm.

Preservice teachers are undergraduate or graduate students who are enrolled in a teacher preparation program with the aspiration of becoming a licensed teacher.

Traditional instruction refers to a method of classroom instruction in which the teacher uses lecture as the primary means of presenting information. This type of instruction rarely consists of student discovery and hands-on manipulative use.

CHAPTER II

Review of the Literature

Lack of Measurement Knowledge

Measurement knowledge is a weakness for students and adults in the United States. The National Assessment of Education Progress (NAEP) data from 1990 to 2003 show that measurement, along with geometry, are the lowest domains for students in the United States (Thompson & Preston, 2004). Logically, weakness in geometry may be due to the weakness in measurement, since measurement is, in part, how a conceptual understanding of geometry is developed. In addition to measurement being a general weakness of U.S. students, the Trends in International Mathematics and Science Study (TIMSS) has repeatedly found that students in the United States perform significantly below many of their international peers in measurement (Gonzales et al., 2004; Mullis, 2000). The TIMSS has shown that while students in the United States perform below many of their international peers in all domains of mathematics tested, measurement is the domain with the largest gap.

The question becomes, why is measurement so difficult for U.S. students? When surveyed, teachers mention that students have a very weak understanding of the metric system of measurement (Thompson & Preston, 2004). The researchers comment that this is likely due to the United States teaching both the metric system and customary system of measures in school (Thompson & Preston, 2004). Even though the metric system is taught in most U.S. schools, Thompson and Preston comment that it is usually taught with a surface-level approach, with little conceptual understanding developed by the students. Battista (2006) documented that students also have a difficult time sorting out different types of measurements, such as length, area, and volume. Measurement can become a list of formulas for students to memorize if it is not taught conceptually.

Evidence from both of the claims by Thompson and Preston (2004) and Battista (2006) can be found in other research. Wilson and Blank (1999) found that unit conversion and measurement estimation were among the worst of items for students in the United States on various NAEP and TIMSS administrations. Taylor, Simms, Kim, and Reys (2001) found that students in Grades 3 and 4 performed much lower on TIMSS items that required knowledge of the general or relative size of metric units than those items that did not require such knowledge. These researchers also mentioned that, in the U.S. midwestern district studied, the metric system was merely mentioned in mathematics classes, though it may have been more substantially addressed in science classes. The authors also provided that approximately 30 days of instructional time were devoted to the customary system as opposed to only 7 days allotted to teach the metric system (Taylor et al., 2001). Another study found that students in the United States, who likely experienced the customary system in their daily lives, performed lower than Mexican students, who used the metric system in daily living activities on measurement items including the estimation of length, coordination of relative size, and understanding of scale (Delgado, 2013). The author notes that there were obviously other variables that may have contributed to the differences observed between these two groups (Delgado, 2013).

As additional studies have documented, measurement is not just an issue for elementary and secondary students (Baturo & Nason, 1996; Buffler, Allie, & Lubben, 2001; Jones et al., 2013; Tariq, 2008). Buffler et al. reported that college students in general have weak measurement skills. They further explained that this weakness in measurement skills led numerous students to avoid careers in the sciences and science classes (Buffler et al., 2001). Tariq found that bioscience undergraduate students had difficulty relating mathematics in general to the real world. In particular, Tariq found that volume, conversion, ratios, and powers of 10, all concepts relating to measurement, were issues for these college students. When studying the content knowledge of student teachers, Baturo and Nason found that many of the prospective teachers only understood area as a single expression of the product of length and width. These prospective teachers had little conceptual understanding of what area meant and that the mentioned expression only works for a limited amount of geometric figures (Baturo & Nason, 1996). Jones et al. (2013) discovered that U.S. teachers and prospective teachers had a weak understanding of scale in comparison to their peers in Austria and Taiwan. The researchers found that U.S. teachers and prospective teachers were outperformed not only in metric scale questions but also in general scale concepts (Jones et al., 2013). Liu and Alagic (2013) found that preservice teachers had very limited knowledge of the metric system accompanied by negative attitudes towards its use. This is possibly an effect of the U.S. teachers and prospective teachers being asked to handle two systems of measurement, while the rest of the world focuses on only one system, the metric system.

The History of the Metric System

In order to frame the problem of a weak understanding of measurement in the United States, the history of the metric system in the United States must be reviewed. As Craig (2012) and Johnson, Norris, and Adams (2007) reported, the United States is the only remaining industrialized nation that does not predominantly use the metric system of measurement. The metric system was developed in France in the late 1700s (Berlinghoff & Gouvea, 2004). Before the metric system, residents of European countries used various units of measure, including body parts such as the hand spans of their political leaders (Berlinghoff & Gouvea, 2004). These units were obviously inconsistent and not easily reproducible. The increase in trade called for a universal system of measurement; enter the metric system. Under Napoleon's influence, many of the countries surrounding France soon adopted the metric system as their own as well (Johnson et al., 2007).

The meter was originally defined as one-ten millionth of the distance from the North Pole to the equator, passing through Paris, France (Johnson et al., 2007). As Johnson et al. highlighted, this original distance was flawed because the shape of the Earth is not exactly spherical, as once was thought. Since its inception, the meter has been redefined many times. The current definition of a meter is the distance light travels in $\frac{1}{299{,}792{,}458}$ second in a vacuum (Johnson et al., 2007).

When the U.S. Constitution was written, measurement was a consideration (U.S. Const. art I, § 8). The Constitution gives the government the right to choose or devise a system of measurements for the nation to use. In fact, in 1789, Thomas Jefferson suggested that the United States adopt a system of measures he devised that had many of the benefits of the metric system, such as being based on powers of 10 (Craig, 2012). The leaders of the United States declined. Shortly after the veto, the metric system was developed in France. If the development of the metric system had come just a few years earlier, then the United States may have adopted the logical measurement system from the beginning.

Throughout history, the leaders of the United States have not completely opposed the metric system. The first legislation towards metrication in the United States came in the Metric Act of 1886. This legislation made it legal for businesses or individuals in the United States to use the metric system. In fact, the United States was one of the original 17 countries to sign the Treaty of the Metre in 1875 (Berlinghoff & Gouvea, 2004). This treaty said that each of the countries would work towards implementation of the metric system to produce consistency internationally. The process of metrication, or converting to the metric system, was a challenge for many of the nations that have taken on the change, but most have become almost completely metric. The United States, however, is still on the fence 139 years later.

In 1916, a group originally called the Metric Association was formed to encourage conversion in industry and education; the group is now called the United States Metric Association (USMA, 2012). In 1948, the National Council of Teachers of Mathematics (NCTM) published its annual yearbook on the usefulness of the metric system and suggested its adoption. Internationally, participants of the General Conference on Weights and Measures formalized the metric system as the Systeme International d'Unites (SI) in 1960 (USMA, 2012). A few years later, the U.S. Metric Study began to assess the reality of converting the United States to the metric system (USMA, 2012). This study recommended that the Unites States should begin using metric units and aim to complete the transformation in 10 years.

The Education Amendments of 1974 urged educators to begin preparing students to use the metric system; yet today, universities still encounter students who are largely unfamiliar with even the structure of the metric system. In 1975, the Metric Conversion

Act was passed to urge industries to voluntarily convert to the metric system. A major weakness of this legislation was the absence of any mandate or deadline for conversion (Johnson et al., 2007). At this time, the U.S. Metric Board was formed to aid industries in the process of metrication (USMA, 2012). As reports from the USMA state, the Metric Board was not well-conceived. President Ford's original nominations included a wide array of representatives from business, science, education, and engineering (USMA, 2012). President Ford's nominations never got passed. President Carter made new nominations, which included no educators and several individuals against metrication (USMA, 2012). One report from the Metric Board that did not receive credence found that the U.S. Government could save $94 million by converting gas pumps to sell gas by the liter instead of converting them to handle prices more than 99.9 cents per gallon (USMA, 2012). In 1978, the Metric Education Act was passed and repealed parts of the Metric Conversion Act of 1975. This act made it legal for grants and other programs to encourage metrication. This act was almost a step backwards for the adoption of the metric system in the United States (Metric Education Act, 1978). At this time, the U.S. Government set the tone that it was through trying to make the nation convert and was leaving the decision to individual consumers and industries.

In the time since the Metric Conversion Act was passed in 1975 and voluntary conversion was encouraged, some industries have made the switch, but consumers and other businesses have refused. In fact, some highway mileage signs can still be found in the United States that list both miles and kilometers to the nearest city (USMA, 2012). A small victory for metric system supporters came in 1988 with the Omnibus Trade and Competiveness Act, which stated that the metric system is the preferred system of the

United States of America. This legislation also required that the federal government operate using the metric system by 1992. With few exceptions, such as mileage signs on highways, this transformation has occurred.

A 1994 amendment to the Fair Packaging and Labeling Act said that products for consumers had to be reported with units from both the metric system and the customary system. Since this time, more industries have found it necessary and beneficial to switch to the metric system. Two such examples are the temperature broadcasts of the National Weather System and the lunar operations of the National Aeronautics and Space Administration (USMA, 2012). Hawaii has recently made a bold move to make the metric system the official system of measurement for all public records including all public school curricula (H.B. 36, 2013).

Scattered events in history indicate that the United States is moving towards being fully metric. However, the United States is extremely slow, and critics may say lazy, in its efforts to adopt the metric system. Individuals question if the nation ever will name an official system of measurement. Until there is some sort of mandated plan for public awareness and education and movement away from customary units, most of the public will likely not convert. Learning and change take sustained effort. If there is no foreseeable payoff or reason to exert such effort, then most of the public will not voluntarily make the change.

Evidence Favoring Complete Conversion to the Metric System

If the United States wants future generations to be able to compete globally, then students need to not only be taught the metric system in school, but the history, significance, and prevalence of international usage of the metric system as well. This usage also needs to be reinforced in measurement tasks in the community and at home. Students need to have numerous experiences with the metric system in order to see and believe in its logical nature. Sterling (2006) recommends that teachers and students can lead the way for national conversion by adequately preparing students to use metric measures.

The metric system is already used in many fields in the United States, such as the military, science, and medicine. Carpentry is one of the few industries that still use the customary system of measures in everyday tasks, but as Craig (2012) indicates, to use the system of measurements in carpentry, one still needs specialized knowledge, such as that a 1" x 2" board is actually 3/4" x 1 ½". Other examples of where the customary system is still used include cooking and sewing.

The advantages of the metric system are obvious when compared to the customary system of measurement. The metric system is based on powers of 10, which make conversions seamless in the base-ten number system. The relationships are consistent among units of length, volume, and mass as noted by prefixes that are used with all three types of measurements. For example, a millimeter is one-one thousandth of a meter, and a milliliter is one-one thousandth of a liter. The logical inter-relatedness of the units in the metric system increases its scientific basis. For example, Sterling (2006) reported that the designers of the metric system intentionally made one milliliter equal to the volume of water in a cubic centimeter at 4 degrees Celsius.

Delgado (2013) cites the consistent use of the more organized, logical metric system as one reason that U.S. students underperform their international peers on measurement tasks. Delgado states that the use of the metric system increases children's understanding of many measurement concepts, including scale. Taylor et al. (2001) also highlight that the use of the metric system builds other mathematical concepts for children such as knowledge of decimals and proportional reasoning.

Aside from the confusion and burden of keeping up with two measurement systems in schools, numerous sources agree that valuable time is being wasted still teaching the customary system at all (Craig, 2012; Oliver & Nichols, 2002; Phelps, 1996; Price, 2001). Craig mentions that not only is time being wasted, but money is being squandered to keep up two sets of measuring tools for both systems in schools nationwide. Phelps claims that about 71 days of instructional time could be saved by teaching only the metric system. Students learn about 17 metric names and relationships as opposed to about 117 different names and ratios for the customary system to gain the same level of fluency in both systems (Phelps, 1996). Students tend to perform better with measurement items relating to the customary system compared to the metric system; the only reason can be its emphasis in school and use at home (Jones, Gardner, Taylor, Forrester, & Andre, 2012).

One major reason the United States has failed to mandate a complete conversion to the metric system is the associated cost. Oliver and Nichols (2002) reported that the cost would have been much lower years ago, when industry was more simplistic. The researchers also reported that a great deal of time would be saved by the mental computations allowed by the use of the metric system (Oliver & Nichols, 2002). Price (2001) documented that the U.S. Government has the resources and means to help industries in the conversion process, something to which other countries that have converted have not always had.

Measurement Instruction

Measurement is a broad domain in mathematics and science. The construct of measurement knowledge entails many skills and diverse understandings. Key concepts relating to measurement instruction that have been recently researched include measurement estimation, unit iteration, and unit conversions.

Measurement estimation can be defined as "the process of determining an approximate measure, the estimate, or an object's length, volume, mass, etc., using mental and visual information" (Subramaniam, 2014, p. 178). Subramaniam also explains that measurement estimation is not simply a guess, but requires logical reasoning. Adams and Harrelll (2003) documented several careers that use measurement estimation often, such as umpires, chefs, and laborers. Measurement estimation is of key importance, because the teaching of many measurement concepts relies on prior knowledge of reasonable answers obtained by estimation. Hanson and Hogan (2000) indicated that there was scant research on measurement estimation because it is difficult to categorize responses. Hanson and Hogan did find that students who did well with estimation also had high math scores on standardized tests. Not surprisingly, the group of students in the study had much more trouble with estimation when it involved decimals as compared to whole numbers (Hanson & Hogan, 2000). Two methods of objectively scoring estimations were found in the literature (Jones et al., 2012; LeFevre, Greenham, & Waheed, 1993). Jones et al. (2012) normalized estimates for different objects by computing a percent error. The method used was to take the absolute value of the difference between the estimate and the actual measure and divide that result by the actual measure (Jones et al., 2012). This allows more room for error for bigger objects.

The method used by LeFevre et al. also allowed for more error on larger objects by awarding 3 points for estimates within 10% of the actual measure, 2 points for estimates between 10% and 20% of the actual measure, 1 point for estimates between 20% and 30% of the actual measure, and 0 points for estimates more than 30% away from the actual measure.

Chang, Males, Mosier, and Gonulates (2011) examined U.S. textbooks' treatment of measurement estimation to find that instruction was quite vague and not explicit. Like many other sources, estimation was treated as a guess and check system (Muir, 2005, 2012). In 2012, Muir highlighted the importance of asking students to reflect upon their estimations after the actual measure is known. Becoming a good estimator requires problem solving and reasoning. Adams and Harrell (2003) recommended that students not only estimate the measure of various objects, present and absent from view, but also find objects that are close to a given measure. Students should begin to realize if they tend to overestimate or underestimate, and adjust accordingly. Alajmi and Reys (2010) found that a group of Kuwaiti students had difficulty recognizing reasonable answers because of their lack of number sense about the relative size of objects and units. The researchers called for more explicit instruction in estimation to combat this issue (Alajmi & Reys, 2010). Jones et al. (2012) found that middle school students were better at estimation involving customary and novel units than when metric units were involved, but also recommended more explicit instruction in estimation.

Unit iteration is another key concept in measurement (Kamii, 2006). Unit iteration is covering a particular distance with consistent units placed end-to-end (Stephan & Clements, 2003). In order for students to learn this principle, researchers recommend that they have experience physically measuring with nonstandard units such as strides or blocks (Lehrer, Jaslow, & Curtis, 2003). A more recent strategy in the research called personal benchmarks may help students gain experience with this idea (Joram et al., 2005). When students have experience developing their own benchmarks for standard units, those benchmarks can sometimes be used to do the physical unit iteration mentioned by Lehrer and colleagues.

A third aspect of measurement that seems to present a problem for students is unit conversion. For example, 1000 m could also be expressed as 1 km. Klamik (2006) documented an observation of many teachers that students often times have a difficult time deciding whether to multiply or divide to obtain a conversion. This issue is a reflection of poor number sense. If students knew about the size of the measurement with which they were working and the relative size of the units to be used, then they should be able to predict an approximate size for the converted measurement. If students knew that the size should be much smaller, then this would help students decide whether to multiply or divide.

As a consequence of the convenient structure of the metric system, shortcuts are sometimes used as instructional methods for unit conversion. With several unit conversions within the metric system, the decimal point appears to magically move to another location within the digits. For example, 312 cm is 3.12 m. The decimal point appears to have just moved two places to the left. Ford and Gilbert (2013) documented common instructional methods for teaching unit conversions, such as a mnemonic to remember the order of the prefixes. One common example is "Kangaroos hop down the mountain drinking chocolate milk," used to recall the orders of magnitude: kilo, hecta, deka, deci, centi, and milli. Ford and Gilbert also mentioned that all too often a shortcut of counting how far apart the prefixes are and simply moving the decimal point is used as the only method of instruction. Indeed, students should recognize a pattern after completing several metric unit conversions, but the pattern should be connected to a conceptual understanding of the base-ten number system and the size of the units. The problem is that when shortcuts such as those mentioned above are the sole methods of teaching the metric system, students often know they have to move a decimal, but do not know which way, how far, and/or how to determine if their answers are even reasonable.

Ford and Gilbert (2013) also mention the factor-label method in which students repeatedly cancel units by multiplying by forms of the number one until the correct units are obtained. For example, students could convert 5 dm to 500 mm by multiplying 5 dm by 100 mm/1 dm, which is equal to one. The issue with the factor-label method is that it is often not taught with conceptual understanding in mind. Students do not recognize that they are just multiplying by one, which is why the amount stays equivalent, and only the form in which it is expressed changes. The recommendation from Ford and Gilbert is that however unit conversions are taught, they should be taught with understanding in mind because of the essential nature of unit conversion in virtually all science careers.

Sterling (2006) offers another approach to create number sense in measurement while teaching the metric system to students. Sterling suggests beginning with a meter stick and finding common items that are about one meter, or creating personal benchmarks for this unit. Also recommended is modeling the general size of the units with hands spread apart, discussing the meaning of the prefixes and relating them to better-known ideas in students' lives (Sterling, 2006). For example, centi refers to one-

one hundredth of the base unit, just like there are 100 cents in one dollar. Sterling recommends using various visuals to help students remember the sizes of units, including a demonstration to show the relationship between one milliliter and one cubic centimeter. Demonstrations like the one described let students see the beauty and organized nature of the metric system and gain appreciation for its use. Questions that ask students to make sense of metric measurements are also suggested (Sterling, 2006). For example, "While hiking, you found a lake that is 20° C. Do you… a. get your ice skates, b. go for a refreshing swim, c. take a warm bath, d. get a tea pot?" (p. 51). A meta-analysis of using hands-on manipulatives to teach mathematics supports the suggestions of Sterling in finding that concrete manipulatives result in a moderate effect size for overall learning (Carbonneau, Marley, & Selig, 2013). A large effect size for retention and small effect size for problem solving were also observed (Carbonneau et al., 2013).

Personal Benchmarks

As previously discussed, measurement estimation is key to understanding actual measurement, no matter which measurement system is being used. Sowder et al. (2010) explained that in order to estimate a measurement, the student must have a mental picture of the units being used or a good feel for the size of the unit. Sowder et al. also recommended that prospective teachers develop a sense of the size of metric units. Base ten blocks, a common mathematics manipulative, were mentioned as a way to help students see relationships between linear units in the metric system, units of area, and units of volume (Sowder et al., 2010).

Various reputable sources have recommended the use of personal benchmarks in measurement instruction, but as Joram et al. (2005) noted, few have actually researched the effectiveness of using this strategy (Joram, 2003; McIntosh, Reys, & Reys, 1992; Muir, 2005, 2012; NCTM, 2006; Subramaniam, 2014). McIntosh et al. stated that knowing a system of benchmarks is a central component of number sense. Muir (2005) argues that personal benchmarks are helpful to students because they make the units more meaningful. Muir (2005) further notes that although body parts are convenient, they often change size as children grow, so should be discouraged as benchmarks. Additionally, benchmarks should not be imposed on students by the teacher; students must develop their own benchmarks so that they are personally meaningful (Muir, 2005). Subramaniam (2014) goes into detail reporting that "benchmarks act as meaningful symbolic representations of units and serve to increase students' understanding of measurement by comparing the to-be-estimated object to an object's whole physical measurement are known through mental imagery" and that this strategy is "prevalent in numerate adults" (p. 183). In other words, students use their prior knowledge to determine reasonable answers or estimates. Joram (2003) and Joram et al. (2005) made a point that benchmarks are not just manipulatives used to actually measure an object; at some point, the process should become mental, and the physical objects should not be touched.

Joram et al. (2005) documented the numerous advantages of using benchmarks in that they make measurement meaningful to students, help students visualize and possibly decrease the number of mental unit iterations needed to estimate an object, and can actually be used for physical measurement if needed. In spite of the benefits of this supposed effective strategy, most students and adults do not use this strategy on their own (Joram et al., 2005). Subramaniam (2014) also found that although prospective teachers sometimes used personal benchmarks in their own work, they did not recognize it as part of their pedagogical knowledge for teaching measurement. For this reason, if benchmarks are to be researched and vetted as an effective instructional strategy, instruction will likely need to be provided on the strategy first.

Three studies were found in the literature investigating the effectiveness of personal benchmarks as an instructional strategy, and all three had significant limitations such as small sample size. Joram et al. (2005) found that third grade students were very weak at drawing representations of standard units and estimating measurements before instruction. After one group of 22 third-graders were instructed on the use of personal benchmarks as a strategy for measurement instruction, and another group of 22 third-graders were instructed on using the guess, check, and reflect method found in many textbooks, the use of personal benchmarks was found to increase the accuracy of drawings of standard units and the accuracy of measurement estimations. Joram et al. (2005) additionally found that in some cases, benchmarks actually made students' estimates less accurate because the benchmarks they were using were inaccurate and poorly developed. These students did better at estimating long, narrow objects as opposed to objects with more pronounced dimensions, like a box. In a similar study conducted by Joram et al. (1998), third grade students who were instructed to imagine something about the size of a standard unit and then draw the standard unit's size were more accurate than those students just asked to draw the unit. Another study found that students did use benchmarks for estimates even without prompting, such as the area of their house to estimate the area of the schoolyard (Gooya, Khosroshahi, & Teppo, 2011).

Gooya et al. also found that students sometimes adjusted their estimates to be more accurate after considering a personal benchmark.

In addition to personal benchmarks possibly increasing estimation accuracy or the recognition of reasonable answers, they may make a difference in the attitudes of students. Liu and Alagic (2013) found that after a group of preservice teachers read about, used, and reflected upon the metric system, their attitudes became more positive about teaching and learning the metric system of measurement. Before the study, the attitudes of the prospective teachers were negative, and a lack of general knowledge about the metric system existed (Liu & Alagic, 2013). After the treatment, the prospective teachers thought the metric system was much more important to the development of children's mathematical understandings and that teachers and local agencies, as well as the federal government had the responsibility to promote its use. Liu and Alagic reported that no existing instrument to assess metric system attitudes could be found, so they created their own assessment of Likert-type items. In addition, they asked the prospective teachers to estimate the measure of two common household items before and after treatment. Although no significant difference in pre and post estimation accuracy was found, there were less outrageous estimates after experience using the units of the metric system in measurement tasks (Liu & Alagic, 2013). The researchers recommended that content courses for preservice teachers include a unit on the metric system because of the need to familiarize prospective teachers with the system of measurement they will be asked to teach (Liu & Alagic, 2013).

The attitudes of preservice teachers towards mathematics may be just as important as their content knowledge of mathematics. Vinson (2001) found that negative attitudes towards mathematics produced negative results in mathematics work. Likewise, Furner and Berman (2005) found that teachers pass their negative attitudes of mathematics on to their students, even without intending to do so. The attitudes of preservice teachers are notoriously poor in regards to mathematics (Bursal & Paznokas, 2006; Vinson, 2001). Vinson states that the poor attitudes are a result of mathematics anxiety, or a fear of doing mathematics. Mathematics anxiety is likely the result of a very procedural instructional background in mathematics. The ideas that there is only one right way to do mathematics and that understanding why mathematics works is not important are detrimental to the attitudes students develop towards mathematics (Gresham, 2007). Gresham stated that attitudes must be addressed along with encouraging multiple ways of thinking about mathematics in order to diminish mathematics anxiety in preservice teachers. The findings of Bursal and Paznokas echoed this belief in determining that preservice teachers experienced less mathematics anxiety and more productive attitudes after experiencing instruction with manipulatives that focused on understanding.

In conclusion, the literature clearly indicates a weakness in measurement for U.S. students. In particular, students are unfamiliar with the metric system of measurement, which is vital to ensuring that they are prepared for many of the careers that await them. Preservice teachers have also shown weakness in the domain of measurement and the metric system. Measurement estimation, recognizing reasonable answers, and unit conversion all are areas of measurement that are essential to everyday tasks and to a solid understanding of measurement. Personal benchmarks are a highly recommended strategy for teaching measurement estimation, and have a theoretical backing from general educational research, but have been researched little on their own. When personal benchmarks have been researched, their use usually led to better estimates and recognition of reasonable answers. The study from Liu and Alagic (2013) suggested that the attitudes of preservice teachers should be investigated along with their content knowledge.

Gaps in the Literature

After a review of the related literature, there seem to be several gaps. Although several sources recommended the use of personal benchmarks, few truly empirical studies were found that investigated their use. No studies were located that investigated the effect of instruction using personal benchmarks on the attitudes and metric system knowledge of preservice teachers. In fact, no studies were located that focused solely on using benchmarks to teach the metric system. It seems logical to investigate these concepts, since there is a documented weakness in both attitudes towards the metric system and knowledge of the metric system in this population. Both the negative attitudes and potential lack of understanding of the metric system are detrimental to the future education of students nationwide if not confronted. The current study aimed to address these gaps by investigating the effect of instruction using personal benchmarks on the attitudes and metric system knowledge of preservice teachers.

CHAPTER III

Methodology

Participants

The participants in this study were 24 preservice elementary teachers in their second elementary mathematics content course at a southeastern U.S. public university. This quasi-experimental study was set in the mathematics course that focuses on forming a conceptual groundwork in measurement, geometry, and algebra concepts taught in kindergarten through eighth grade. The mean and median ages of participants were 29 and 21 years, respectively. Additional demographics for participants are listed in Table 1.

Table 1

Demographic Characteristics of the Participants

Demographic		Frequency	Percentage
Gender			
	Male	2	8.7
	Female	21	91.3
Race			
	White	19	82.6
	Black	4	17.4
	Asian	3	13.0
	Hispanic Origin	1	4.3
Student Classification			
	Traditional	18	78.3
	Nontraditional	5	21.7

Note. $n = 23$. Some participants identified with more than one race, which is why the percentages do not total 100%. Additionally, other races were available to select on the demographics form; however, no participants selected these, so they were left off of the table.

Participants were chosen as a sample for the study because they were already enrolled in a course where measurement content would be taught. In order to have access to instruction over a period of time, their enrollment in a course addressing measurement was ideal. Their early matriculation through their program of study to become elementary teachers also made them a desirable population because they had not received much formal instruction on teaching and learning measurement. Participants were given the option to opt out of the pre and postsurveys without their instructor's knowledge of their decision, so as to not feel undue pressure to participate. There was no compensation for participation in the study, and nothing extra was required of participants beyond the completion of both surveys. Permission to study these research questions with this sample was given by the Institutional Review Board at the university at which they were attending (Appendix B).

Instrumentation

The independent variable has two levels, instruction on using personal benchmarks and the more traditional instruction using non-contextual visuals to represent unit sizes. This study sought to find if relating standard units to familiar items, called personal benchmarks, helps preservice teachers make sense of the metric system and embrace its importance.

Faculty-generated metric system knowledge survey. There were two dependent variables in this study. The first dependent variable was knowledge of the metric system. No existing assessment of metric system knowledge was located in the reviewed literature, so a faculty-generated instrument was created to assess this variable. All items were modeled after those found in previous research studies (Joram et al., 2005; Liu & Alagic, 2013) or located in the research-based textbook used for the course used in the study (Sowder et al., 2010). From reviewed literature, knowledge of the metric system for preservice teachers should include knowing the general and relative sizes of familiar units in the metric system, understanding the base-ten structure of the measurement system, and using that knowledge to complete unit conversions within the metric system. Knowledge of the size of familiar units was assessed both by having preservice teachers estimate the size of familiar objects and decide if given estimates are reasonable or unreasonable, and justify their reasoning. The literature also suggests that areas of difficulty in measurement tasks involve two or three-dimensional measures and decimal values. In order to ensure a proper level of rigor for the assessment being used with prospective teachers, both of these types of items were incorporated in the estimation and conversion tasks.

The assessment instrument for knowledge of the metric system included three estimation tasks using various metric units, five unit conversion tasks, and two questions that asked participants to determine whether a given estimate was reasonable or unreasonable. The possible points earned to measure knowledge of the metric system ranged from zero to ten. The last question on the questionnaire asked participants which method of completing unit conversions they preferred to use and why. This question sought to provide the researchers with knowledge of the conversion methods preservice teachers knew before entering the course, and which ones they preferred to use after several methods had been discussed. In order to provide objectivity, the estimation items were scored depending on the proximity of the estimate to the actual measure of the object. Inter-rater reliability of 100% was established by checking the calculations twice, once using Microsoft Excel, and again by hand. The percent error of the estimate was calculated and subtracted from one, to create greater scores for closer estimates. Unit conversion items were scored as correct or incorrect. Items that asked participants to decide whether a given estimate is reasonable or unreasonable were scored as correct or incorrect as well. Unreasonable answers were defined in this study as those that vary more than 50% from the actual measure taken.

Beliefs towards the metric system survey. The second dependent variable was the attitudes of preservice teachers concerning the metric system. An instrument was located that measured this construct in a study by Liu and Alagic (2013). The instrument asks preservice teachers' opinions on the usefulness of the metric system, the importance of teaching the metric system to children's development of mathematical knowledge, and who should be responsible for the implementation of the metric system in the United States. The questionnaire includes 14 statements that preservice teachers rate on a Likert-scale ranging from 5 = "Strongly Agree" to 1 = "Strongly Disagree." All items on the instrument were checked to ensure that "Strongly Agree" was the most favorable choice, indicating the most positive perception of the metric system. The range of possible scores on this instrument was 14-70. A high level of internal reliability was established by Liu and Alagic (2013), giving alpha indexes of 0.89 and 0.84 for the pre and postsurvey items, respectively.

Both the pre and postsurveys for the measurement of both variables are in Appendix A.

Procedure

The preservice teachers in the study were already enrolled in two sections of the course, so random assignment was not used in this study. The decision of which section received which type of instruction was be decided by the flip of a coin. Because the researcher was also the instructor for both sections of the course, the study was described to participants and all assessment instruments were proctored by an unrelated faculty member while the instructor was out of the room.

Both sections completed many measurement and estimation tasks central to the focus of the measurement unit, and all tasks were the same except for the way standard units were discussed. In the section experiencing personal benchmark instruction, students searched around the room and in their homes to find objects that were familiar to them that had the same relative size as the main standard units discussed in this unit (i.e., millimeter, centimeter, decimeter, meter, kilometer, and liter). Area units and volume units associated with centimeters, decimeters, and meters were also discussed and used in both sections.

The more traditionally instructed section looked at the various standard units represented as lengths on the board and a beaker that held one liter. Both sections discussed methods of completing unit conversions that they already knew, such as the factor-label method, using a mnemonic device, or a two-column table. Both sections estimated the measure of multiple items in one, two, and three dimensions, checked their estimates, and reflected on their accuracy. Additionally, both sections of the course used metric units to measure on nearly all tasks throughout the unit on measurement. Both sections received the same amount of instruction, the same homework problems, and received instruction from the same instructor. Instruction lasted for approximately three weeks, taking place in 55-minute sessions three times per week. Participants took a presurvey the week before instruction began and completed the postsurvey at the end of the week that instruction ended for the unit. Both surveys were given on hard copies, with all additional materials removed from site and no access to a calculator. Students were assigned an identification number by the proctor so that the instructor could not connect individual responses back to any student.

Statistical Analysis

The independent variable in this study had two levels, instruction using personal benchmarks or more traditional instruction using non-contextual drawings. The samples were independent in that no participant was assigned to both groups. The two dependent variables included participant scores on the postsurveys for knowledge of the metric system and beliefs towards the metric system. The presurvey scores for both surveys were used in this study as covariates because random assignment of individuals to the two levels of the independent variable was not possible. Both variables of metric system knowledge and beliefs towards the metric system were assumed to have underlying continuity and were considered continuous for the purposes of statistical analysis. (Malhotra, Agarwal, & Peterson, M., 1996; Norman, 2010). Even though single Likert-type items are of ordinal nature, the construct of beliefs towards the metric system, operationalized by the sum of the 14 Likert-type items, can be treated as quantitative data and analyzed as such (Liu & Alagic, 2013).

Because it was not possible to randomly assign participants to each of the two treatment groups, using the participants' preexisting knowledge and beliefs about the metric system as covariates served to remove some of the error variance attributed to the initial differences between the groups in these areas. This type of analysis is commonly used when random assignment is not possible (Hinkle, Wiersma, & Jurs, 2003). Because of the nature of the variables and the design of the study, an analysis of covariance

(ANCOVA) at the 0.05 probability level ($\alpha = 0.05$) was selected to address each research question. The probability level of 0.05 is commonly accepted in educational research as a sufficient level of significance for most studies (Hinkle, Wiersma, & Jurs). The independent samples, continuity of the dependent variables and covariates, and the discrete, categorical independent variable meet the first three assumptions for using an ANCOVA. Data were analyzed using the Statistical Package for the Social Sciences (SPSS) 22.0 software.

CHAPTER IV

Results

The statistical analysis of this study was two-fold. It started with a between-groups comparison of metric knowledge, which was followed by a between-groups comparison of beliefs towards the metric system. The following chapter was organized into two sections to separately address these two analyses.

Knowledge of the Metric System

Descriptive analysis of the dependent variable and covariate. The means, standard deviations, and ranges for both the presurvey on knowledge (covariate) and postsurvey on knowledge (dependent variable) are listed in Table 2.

Table 2

Descriptive Statistics for Knowledge of the Metric System

	Presurvey (Covariate)			Postsurvey (Dependent Variable)			
Instructional Group	*M*	*SD*	Range	*M*	*SD*	Range	*N*
Personal Benchmarks	4.173	1.181	3.700	4.947	1.867	6.590	12
Traditional	4.619	1.937	5.410	4.317	1.100	3.440	11
Totals	4.386	1.567	5.410	4.646	1.548	6.590	23

Both the covariate and the dependent variable were checked for normality and significant outliers, two more assumptions of an ANCOVA. The distributions of scores on both of these measures are shown in Figures 1 and 2. Both distributions were approximately normal, with no outliers beyond two standard deviations from the means.

The furthest deviation from the mean occurred in post knowledge, where the data point 8.4 was approximately 1.8 standard deviations above the mean for the treatment group. In addition, linearity between the covariate and dependent variable is shown in Figure 3. Pearson's r for this correlation was 0.048. Surprisingly, this test showed almost no relationship between pre and postknowledge. This finding, in conjunction with the main effect of pretest knowledge on posttest knowledge, $F(1, 21) = 0.143, p = 0.709$, suggests that preknowledge was not necessary as a covariate and produced similar results to an analysis of variance between the two groups, $F(1, 21) = 0.947, p = 0.342$.

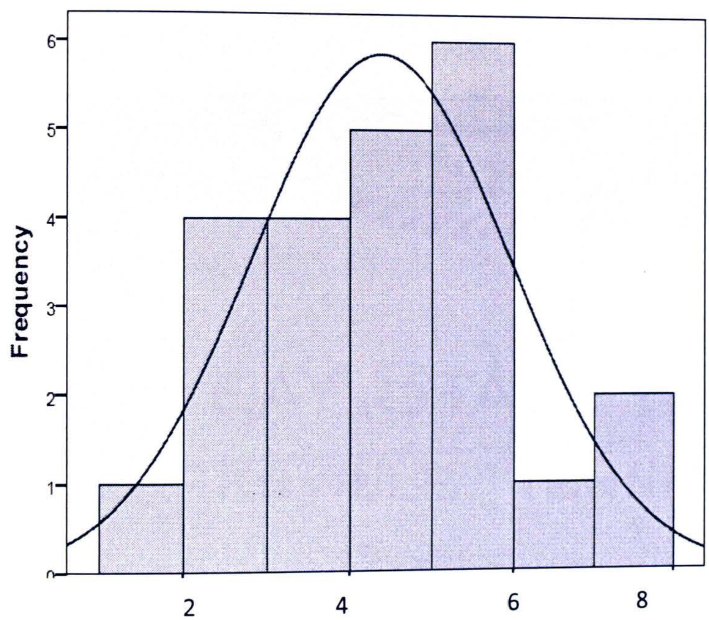

Figure 1. Distribution of scores on Knowledge of Metric System Presurvey

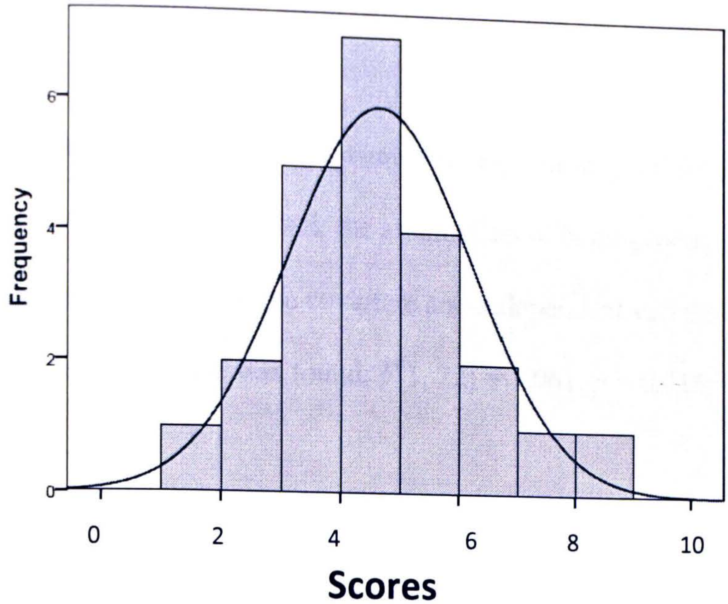

Figure 2. Distribution of Scores on Knowledge of Metric System Postsurvey.

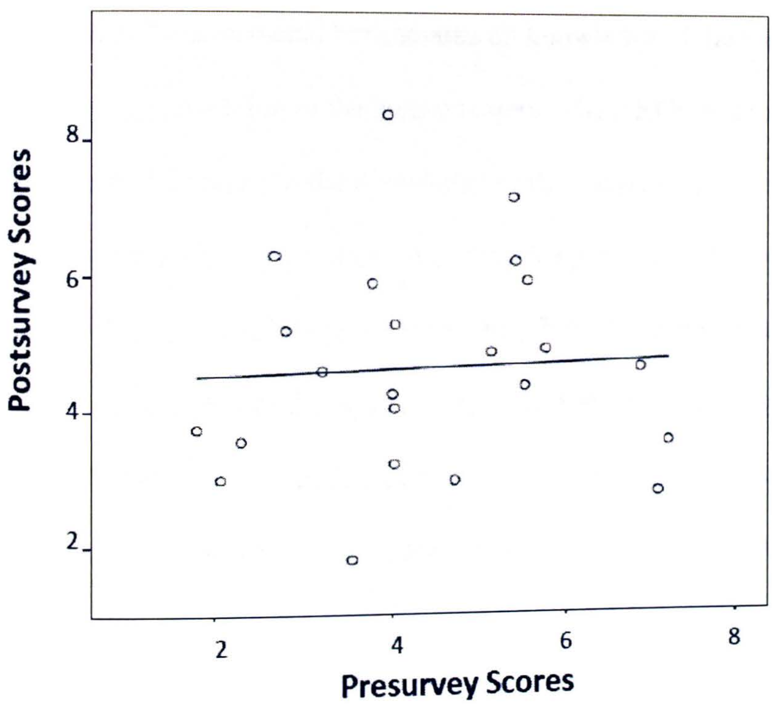

Figure 3. Linearity between Covariate and Dependent Variable (Knowledge).

Assumption of homogeneity of variances. Levene's test was used to check the assumption of homogeneity of variances, $F(1, 21) = 1.603$, $p = 0.219$, indicating that there was no statistically significant difference in the variances and the assumption was met.

Assumption of homogeneity of regression. A two-way analysis of variance (ANOVA) was used to check the assumption of homogeneity of regression by examining the interaction between the covariate and independent variable. No statistically significant difference was found, $F(1, 22) = 1.061$, $p = 0.316$; therefore, the assumption was met.

Results of the ANCOVA. Upon meeting the all the assumptions, a one-way ANCOVA was conducted to determine statistically significant differences between students who experienced traditional instruction and students who experienced instruction using personal benchmarks on knowledge of the metric system controlling for preexisting knowledge of the metric system. The ANCOVA revealed no statistically significant difference in the knowledge of the metric system among preservice teachers in the two treatment groups after controlling for preexisting knowledge as a covariate, $F(1, 22) = 0.995$, $p = 0.330$. The results of the ANCOVA are summarized in Table 3. These results showed that students who experienced instruction using personal benchmarks ($M = 4.947$) did not have significantly higher knowledge of the metric system, controlling for preexisting knowledge, than students who experienced traditional instruction ($M = 4.317$). An effect size was calculated using partial eta squared, and this indeed showed little to no effect, ($\eta_p^2 = 0.047$).

Table 3

Analysis of Covariance Summary for Knowledge of the Metric System by Type of Instruction

Source	*SS*	*df*	*MS*	*F*	*p*
Preknowledge	0.358	1	0.358	0.143	0.709
Treatment Group	2.493	1	2.493	0.995	0.330
Error	50.082	20	2.504		
Total	52.714	22			

Beliefs towards the Metric System

Descriptive analysis of the dependent variable and covariate. The means, standard deviations, and ranges for both the presurvey on beliefs (covariate) and postsurvey on beliefs (dependent variable) are listed in Table 4.

Table 4

Descriptive Statistics for Beliefs Towards the Metric System

	Presurvey (Covariate)			Postsurvey (Dependent Variable)			
Instructional Group	*M*	*SD*	Range	*M*	*SD*	Range	*N*
Personal Benchmarks	51.417	6.694	21.000	54.250	6.107	17.000	12
Traditional	48.455	6.424	23.000	53.818	5.528	18.000	11
Totals	50.000	6.592	24.000	54.043	5.709	30.000	23

Both the covariate and the dependent variable were checked for normality and significant outliers, two more assumptions of an ANCOVA. The distributions of scores on both of these measures are shown in Figures 4 and 5. Although both distributions deviated from normality, the ANCOVA is robust against this violation if the sizes of the treatment groups are approximately equal (Hinkle, Wiersma, & Jurs, 2003). The furthest deviation from the mean was the data point of 65 for the covariate. This score deviated approximately 2.2 standard deviations from the mean for that group. All other data points were within 1.8 standard deviations from the means for their respective groups. In addition, linearity between the covariate and dependent variable is shown in Figure 6. Pearson's *r* was 0.479.

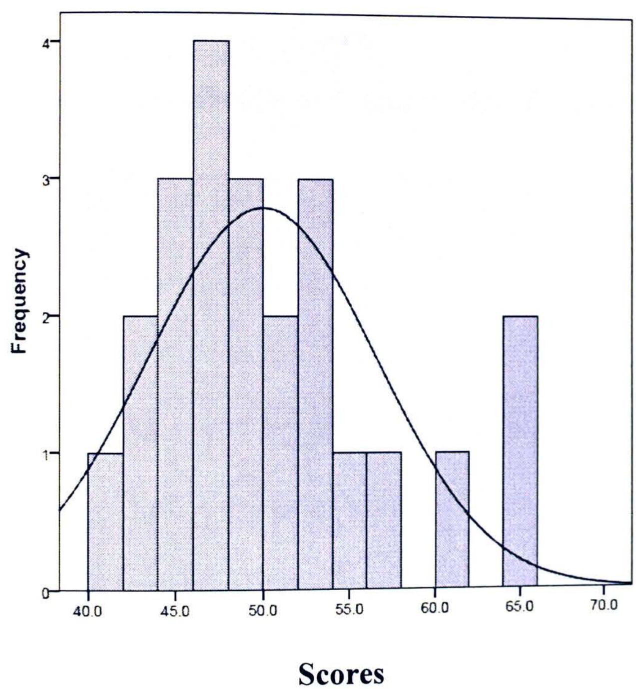

Figure 4. Distribution of Scores on Beliefs towards the Metric System Presurvey.

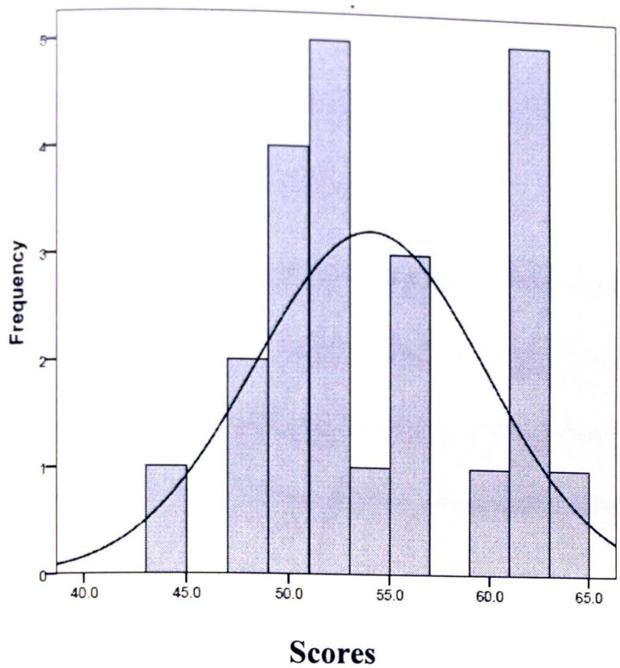

Figure 5. Distribution of Scores on Beliefs towards the Metric System Postsurvey.

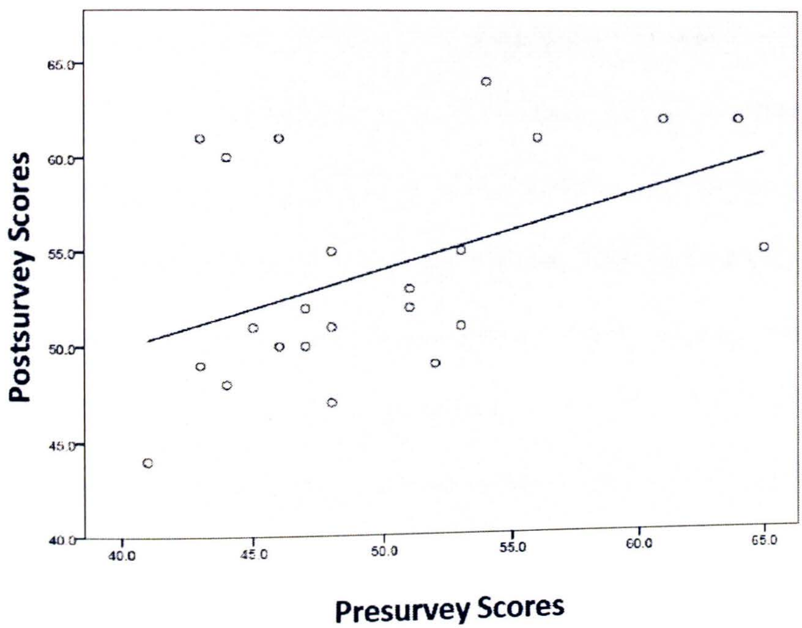

Figure 6. Linearity between Covariate and Dependent Variable (Beliefs).

Assumption of homogeneity of variances. Levene's Test was used to check the assumption of homogeneity of variance, $F(1, 21) = 0.224$, $p = 0.641$, indicating that there was no statistically significant difference in the variances and the assumption was met.

Assumption of homogeneity of regression. A two-way analysis of variance (ANOVA) was used to check the assumption of homogeneity of regression by examining the interaction between the covariate and independent variable. The result was $F(1, 22) = 0.018$, $p = 0.895$. There was no statistically significant difference, thus meeting the assumption.

Results of the ANCOVA. Upon meeting the previous assumptions, a one-way ANCOVA was conducted to determine statistically significant differences between participants who received personal benchmarks instruction and participants who received more traditional instruction on beliefs towards the metric system, controlling for preexisting beliefs. The ANCOVA indicated that students who received personal benchmarks instruction ($M = 54.250$) did not have significantly more positive beliefs towards the metric system than students who received more traditional instruction ($M = 53.818$) after controlling for preexisting beliefs, $F(1, 22) = 0.136$, $p = 0.717$. An effect size was calculated using partial eta squared, which showed little to no effect ($\eta_p^2 = 0.007$). A with a small effect size (partial eta squared = 0.007). The analysis did show a statistically significant increase in beliefs overall, $F(1, 22) = 0.5.954$, $p = 0.024$, $\eta_p^2 = 0.229$ (partial eta squared). The results of the ANCOVA are summarized in Table 5.

Table 5

Analysis of Covariance Summary for Beliefs towards the Metric System by Type of Instruction

Source	*SS*	*df*	*MS*	*F*	*p*
Prebeliefs	164.229	1	164.229	5.954	0.024
Treatment Group	3.742	1	3.742	0.136	0.717
Error	551.657	20	27.583		
Total	716.957	22			

CHAPTER V

Discussion

Knowledge of the Metric System

The first research question sought to find the effect of using personal benchmarks while teaching elementary mathematics content on preservice teachers' knowledge of the metric system. The corresponding research hypothesis was that the metric system knowledge of preservice teachers who were taught personal benchmarks as part of instruction would be significantly different than the knowledge of those who experienced more traditional instruction. The first null hypothesis that there would be no difference in metric knowledge between the two groups of preservice teachers after controlling for preexisting knowledge failed to be rejected because the study found no statistically significant difference in metric knowledge between groups.

Many sources recommend personal benchmarks as an effective way to teach students about the general size of standard measurement units (Joram, 2003; Joram et al., 2005, Sowder, Sowder, & Nickerson, 2010). Personal benchmarks may be an effective strategy, but this study failed to support that claim. Perhaps mathematics educators need to reexamine these recommendations and consider why this method is not working and what other methods should be considered. This finding indicates that additional research should be conducted testing the effectiveness of personal benchmarks as an instructional tool as well as testing the effectiveness of other strategies. In theory, using benchmarks should be effective because the strategy relates abstract units to concrete materials and prior knowledge. Connecting new knowledge to preexisting knowledge is widely supported by research (Marzano, Pickering, & Pollock, 2001). Students had many prior experiences seeing the metric units used in daily activities. The act of associating the units with more familiar items should make them more meaningful and more memorable. Additionally, using personal benchmarks as part of instruction has components that should appeal to both kinesthetic and visual learners. Designing instruction that caters to different types of learners is supported by the Theory of Multiple Intelligences (Gardner, 2011). When information is presented in a way that accommodates different learning styles, students should be more successful. So why did the participants in this study not show significant growth in metric system knowledge for either type of instruction?

There may be several reasons that no statistically significant difference was observed in this study, including the various limitations of the study. The preservice teachers in this study have had years of experience with the metric system through previous courses and their daily living activities. While these experiences may seem like they would help participants' knowledge of the metric system, not all of these experiences have been positive or mathematically accurate. For example, some preservice teachers had been using rulers marked by the centimeter for more than ten years, but had thought that they were measuring in millimeters. Some preservice teachers had a general fear of the metric system and resistance to even using the units of measure in class. In class discussions, several students shared stories about how much they disliked or felt anxiety towards using metric units and stated that using the metric system was too difficult. As a result of questioning these students, it became clear that many of their previous experiences with learning the metric system had been based on memorization and not on understanding the relative size of the units and making sense of the underlying mathematical concepts. The limited conceptual understanding of the metric system observed and resistance to embrace the metric system may be too engrained in this population to change over the period of one short instructional unit. There may be an underlying problem in the general unpreparedness of many preservice teachers in relation to the concepts that relate to the metric system, such as the structure and logical nature of the base-ten number system. If this understanding is not present, then it would be difficult for participants to understand the simplicity of many conversions within the metric system and how the different units relate to each other. For example, some participants did not demonstrate understanding of the concept that if 10 mm = 1 cm, then 20 mm = 2 cm. This lack of proportional reasoning can be detrimental to any hopes of understanding equivalence relationships no matter what measurement system is being considered. Perhaps more time and even more diverse experiences need to take place for meaningful change to occur since the misconceptions are so deeply rooted in some preservice teachers.

Interestingly, many of the participants performed much better on the concepts surrounding the metric system on their final exam that took place a few weeks after the postassessment for this study. Although it was outside the scope of this study to analyze those differences, studying these in the future may further support the claim that some participants did not complete the postassessment items to the best of their ability. Maybe participants were unwilling to try their best on the assessments unless they counted for a grade. This observation hints at a threat to construct validity, because the knowledge survey may not have actually measured knowledge as well as was intended. Ensuring that participants take both assessments seriously and complete the problems to the best of their ability should be a consideration in future studies.

Beliefs towards the Metric System

The second research question sought to find the effect of using personal benchmarks while teaching elementary mathematics content on preservice teachers' beliefs towards the metric system. The corresponding research hypothesis was that the beliefs towards the metric system of preservice teachers who were taught personal benchmarks as part of instruction would be significantly different than the beliefs of those who experienced more traditional instruction. No statistically significant difference in beliefs were found between the two groups of preservice teachers, so the researcher also failed to reject the second null hypothesis that there would be no difference in beliefs towards the metric system between the two groups of preservice teachers after controlling for preexisting beliefs.

Although no difference in beliefs towards the metric system was found between the two groups of participants, a statistically significant difference in beliefs towards the metric system was observed as a main effect. It is possible that the method of instruction may not affect beliefs as much as the discussions and internal reflections that take place in a general classroom environment. This result may indicate that having preservice teachers discuss, use, and reflect upon the metric system creates a more positive perspective of the metric system among this group. This change in beliefs could be due to preservice teachers simply having the opportunity to discuss an unfamiliar system with peers in a constructive way. Additionally, students had multiple experiences in using metric units to measure various items over the course of this unit. These experiences may have helped the preservice teachers become more comfortable and confident in using and teaching the metric system. Studies have previously linked positive dispositions towards mathematics to increases in content knowledge (Leatham, 2006; Wilkins, 2008). Perhaps creating more positive dispositions towards the metric system is just the first step in preservice teachers becoming more confident in the content surrounding the system. This could be further supported by comparing the questions about metric system knowledge on the participants' final exams with their post assessment scores. In the time period between the postassessment and final exam, participants had the chance to internalize their beliefs, reflect upon the metric system as a whole, and review the content both on their own and with the class. Any one of these events or a combination of them could have contributed to their increased demonstration of mastery on the final exam.

Implications for Teaching and Policy

There is no doubt that the United States is using the metric system more and more. Employees in various career fields, teachers, students, and consumers will all need to eventually become confident and knowledgeable about the standard units used in this measurement system. Employers and teachers need to know the most effective instructional strategies for creating this knowledge base. Personal benchmarks may be part of the solution or they may not be, but more research needs to be done to investigate this claim. Additionally, the results of this study suggest that having individuals talk about the benefits of the metric system and use the metric units in everyday activities may create more positive beliefs towards using the metric measurement system. Having individuals participate in estimation, conversion, and measuring tasks using both systems can highlight the logical nature and convenient base ten structure of the metric system, creating a feeling of appreciation.

Because individuals are inherently resistant to change, governance bodies need to take on more of a leadership role in mandating and facilitating the United States' use of the metric system. Even though current mathematics standards in many locations advocate the teaching and use of the metric system, the customary system is still given priority in many of these places because of its familiarity to both teachers and students. Teachers need professional development opportunities that focus on how to portray the metric system in a positive nature and advocate for its use. Even though some jobs still require knowledge of the customary measurement system, the proportion of careers that use the metric system continues to increase. Considering that teachers are preparing their students for careers that do not even exist at this time in a competitive global economy, students need to develop proficiency in using the metric system in the early grades and put that knowledge to use in the upper grades.

Future Research

This study serves as a starting point for several future projects. The study assumed that participants would answer truthfully and to the best of their ability on the survey in regards to their beliefs about the metric system and basic knowledge of the metric system. Given the lack of correlation between the covariate and dependent variable for knowledge of the metric system, this may have been a false assumption. As previously stated, the possibility that this assumption was false presents a threat to construct validity.

Certain limitations were present in this study. One severe limitation is that the available sample was one of convenience and was limited in size, with $n = 23$. These two aspects of the sample limit the generalizability of the findings and present a potential threat to external validity. This study did not represent a true experiment in that the two sections of the course were predetermined, so random assignment of individuals was not feasible; however, the choice of which section received benchmark instruction was random. In addition, the time period between the pre and postsurveys was one month, which may not have been enough time for meaningful change in knowledge or beliefs to occur. Additional limitations include that some students in both sections were absent for part of the instruction during the timing of the study, and this could have affected any gains they may have experienced in knowledge or beliefs due to the activities and discussions that took place in the classroom. One limitation that was not anticipated was that some participants may not have tried their best on the assessments because there was no consequence to performing poorly or leaving items blank. On the postassessment, several questions were left blank, which could have negatively affected the correlation between pre and postknowledge.

This study can lead the way to future studies in measurement instruction. First, the study could be repeated with a larger, more diverse population of preservice teachers to see if the results are similar. Improvements to the instruments, including reliability of the knowledge instruments, should be considered before using them in a subsequent study. The knowledge instruments used in this study combined estimation, conversions, and recognizing reasonable estimates as components of knowledge about the metric system. It may be beneficial to study these components individually and determine if any other components to metric system knowledge should be studied.

In the future, personal benchmarks should continue to be studied as an instructional strategy for teaching measurement concepts, both with preservice teachers, teachers, elementary and secondary students, and individuals in other career fields. The potential studies could improve upon the current study by providing a more substantial experience during the treatment phase. Because of the time frame for completion and how the measurement unit fit within the structure of the existing mathematics content course, an extended period of time focusing only on the metric system was not feasible.

In conclusion, both null hypotheses in this study failed to be rejected; however, personal benchmarks need to continue to be researched with a larger population, perhaps in a study that is not confined by the nature of a preexisting course. Teaching the metric system is a concern for mathematics educators, science educators, and employers across the United States. Whatever the best methods are for creating proficiency with, and support of, this system, these methods need to be further researched and disseminated to the individuals who need them most.

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APPENDICES

APPENDIX A

Institutional Review Board Letter of Approval

AUSTIN PEAY STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD

Date: 9/9/2014

RE: 14-040 Investigation of instructional strategies commonly used to teach metric sense

Dear Audrey Bullock,

Thank you for your recent submission to the APIRB. We appreciate your cooperation with the human research review process. Your study has been reviewed on an expedited basis, and is approved.

This approval is subject to APSU Policies and Procedures governing human subject research. The full IRB may still review this protocol and reserves the right to withdraw expedited approval if unresolved issues are raised during their review.

You are free to conduct your study. This approval is for one calendar year and a closed study report or request for continuing review is required on or before the expiration date, 9/9/2015. If you have any questions or require further information, you can contact me by phone (931-221-6106) or email (shepherdo@apsu.edu).

Sincerely,

Omie Shepherd

Omie Shepherd, Ph. D. Chair, APIRB

Cc: John McConnell III

APPENDIX B

Pre and Postsurveys for Knowledge and Beliefs

Presurvey Demographics

Your responses to the following questions are completely anonymous and will in no way be connected back to your name.

1. Gender (please circle any that apply): Male Female

2. Ethnicity (Please circle all that apply):

   Caucasian African American
   American Indian or Alaska Native
   Hispanic Origin Asian
   Native Hawaiian or Pacific Islanders
   Other________________________

3. Student Classification (please circle one):
   a. Traditional (entered college immediately out of high school)
   b. Nontraditional (one or more years between high school and college)

4. Age_______________

Presurvey and Postsurvey Questions for Beliefs towards the Metric System

For questions 5-12 below, please circle the response that best describes how you feel about the statement.

5. For the *metric* system (meters, kilograms, liters, etc.):

   a. I am comfortable in using it.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

   b. I am comfortable in teaching it.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

   c. It is easier for teachers to teach.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

   d. It is easier for students to learn.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

   e. It is easier for students to use.

Strongly Disagree Disagree Neutral Agree Strongly Agree

6. The use of metric system is important …

   a. in children's development of mathematical concepts in general.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

   b. in children's development of the base-ten number system.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

   c. in children's development of the understanding of place-value.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

7. Teacher preparation programs should prepare future teachers about how to use the metric system.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

8. School districts should offer their teachers workshops on how to *use* the metric system.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

9. School districts should offer their teachers workshops on how to *teach* the metric system.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

10. Switching to the metric system will be useful to American students' future lives.

    Strongly Disagree Disagree Neutral Agree Strongly Agree

11. Students' *learning* of the metric system should be promoted.

    Strongly Disagree Disagree Neutral Agree Strongly Agree

12. Students' *using* of the metric system should be promoted.

    Strongly Disagree Disagree Neutral Agree Strongly Agree

Presurvey for Knowledge of the Metric System

Please answer the following questions to the best of your ability. Show your thinking/explain where appropriate, and provide your final answer on the indicated blank.

13. Estimate the length of a new, unsharpened pencil in centimeters.

____

14. Estimate the capacity of a soda can in milliliters. ________________

15. Estimate the area (amount of flat space) of the front of a U.S. one-dollar bill in square centimeters. ______________________________

16. 0.62 km = __________ m

17. 29 cm = __________ dm

18. 56 mg = ____________ g

19. 78 cm^2 = ____________ dm^2

20. 1.4 m^3 = ____________________ cm^3

21. Are the following claims reasonable or unreasonable estimates?

    a. The area of Post-it note is about 60 cm^2. ______________________

    b. The volume of a shoe box is about 211 dm^3. ____________________

22. Do you recall ever being taught to do metric conversions, like problems 16-18 above?

    Yes No

    If yes, please describe the methods you remember learning, even if you only remember a little bit of the method.

Postsurvey for Knowledge of the Metric System

Please answer the following questions to the best of your ability. Show your thinking/explain, and provide your final answer on the indicated blank.

1. Estimate the length of a new, unsharpened pencil in centimeters.

   ____

2. Estimate the capacity of a soda can in milliliters. ________________
3. Estimate the area (amount of flat space) of the front of a U.S. one-dollar bill in square centimeters. ________________________
4. 0.51 km = __________ m
5. 35 cm = ___________ dm
6. 72 mg = ______________g
7. 96 cm^2 = _____________dm^2
8. 1.2 m^3 = ______________________cm^3
9. Are the following claims reasonable or unreasonable estimates?
   a. The area of Post-it note is about 60 cm^2. ________________________
   b. The volume of a shoe box is about 211 dm^3. ______________________
10. What is your method of choice for completing conversions like those in #12-16 above? Why?