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Employment of an Informal Educational Mathematical Facility to Lower Math Anxiety and Improve Teacher and Student Attitudes Towards Understanding Mathematics

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Employment of an Informal Educational Mathematical Facility to Lower Math Anxiety and Improve Teacher and Student Attitudes Towards Understanding Mathematics

by

Vicki Adams

A Dissertation submitted to the Education Faculty of Lindenwood University

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Employment of an Informal Educational Mathematical Facility to Lower

Math Anxiety and Improve Teacher and Student Attitudes

Towards Understanding Mathematics

by

Vicki Adams

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Dr. William Emrick, Dissertation Chair	July 5, 2012 Date
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Declaration of Originality

I do hereby declare and attest to the fact that this is an original study based solely upon my own scholarly work here at Lindenwood University and that I have not submitted it for any other college or university course or degree here or elsewhere.

Full Legal Name: Vicki Adams

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"Mathematics is the pen in which God has written the universe". Galileo

Abstract

Students do not pursue careers in science, technology, engineering, or mathematics (STEM) because of a lack of ability, but rather a lack of positive experiences with mathematics. Research has concluded that attitudes in math directly influence success in mathematics. As many as 75% of high school graduates in the United States suffer from mild to severe forms of math anxiety. The improvement of student achievement in mathematics in the United States lags behind that of many other nations in the world. Efforts to improve student achievement in mathematics have focused on developing effective teachers and teaching practices, creating state and national standards, and raising test scores. Advances in neuroscience and understanding how the brain learns mathematics are often not reflected in current instructional practices, and being “bad at math” is not viewed as a problem by American society. As a response to the current state of mathematics in the United States, the researcher created an informal educational center to provide positive mathematical experiences that demonstrate how math works. The Metamo4ic Math Center opened in 2007.

This study investigated the effectiveness of a two-hour field trip visit to the Math Center on 114 elementary students, six teachers, and 42 preservice teachers. A Math Anxiety Scale - Revised (MAS-R) and knowledge concept map were administered to treatment and control groups pre-visit, post-visit, and post-post visit. Interviews were conducted pre and post visit. In addition, an independent evaluator observed each field trip visit.

The results of the study indicated that the Math Center does significantly lessen anxiety and reduce negative attitudes toward mathematics in elementary students and their teachers. Although pre-service teachers demonstrated a lessening in anxiety, the decrease was not significant, and the results demonstrated that the pre-service teachers in both the treatment and control groups had anxiety levels significantly higher than the student and in-service teacher groups. This study led the researcher to conclude that a "Cycle of Anxiety" is contagious and continually perpetuated through the current instruction of mathematics. This study indicated that efforts to improve math achievement void of addressing negative attitudes and math anxiety might not be successful.

Preface

Every life compares to a piece of uniquely crafted cloth, a human textile woven from the warp of our human being and interlaced with the weft derived from our personal experiences. This artistic woven reality displays the life journey of an individual. A long piece of cloth denotes a long life while a short piece of fabric tells the story of a person who was here for a brief time. The texture of the cloth reveals the strength of the warp, the beauty and talent that lie within us, and life's encounters and experiences, which are the weft, woven through the warp, and manifest themselves in a pattern that perfectly portrays the individual's life.

The design of my material is different from that of most educators. My warp originated from the most marvelous mother on the planet and from one of the most perplexing individuals on the planet, my father, an architect, driven by the warp from his own cloth. The weft of my life depicts a texture that is bumpy, sometimes soft, but always colorful.

After many personal failures, forever woven into my tapestry, I enrolled in college at the age of 36. As a divorced single mom, I worked two jobs to raise my two children, and with the help and support of my parents and some wonderful friends, I graduated with a degree in Elementary Education two days before I turned 40. As it turned out, being 40 did not make it easy to find a job. In fact, I had given up looking for a teaching position when I received a phone call after the start of the 1998-1999 school year. There were too many children in the third grade classes, the board had just approved the addition of another class, and the principal wanted me to teach that class. I am so very thankful to that principal for having faith in me and giving me the opportunity to begin what I was born to do…teach! I have since discovered, that being a teacher is not what I do, but rather it is who I am.

Not only should we thank the people who offer us opportunities, but we must also thank the people who stand and block our way through the door for they inspire us to open a window, and open a window I did. Although in education, we make decisions based on data, research, and best practice, I cannot report that this window, The Metamo4ic Math Center followed that process, but instead was created on what I intuitively understand about learning. A line from the movie, *The Land Before Time*, best says it all, "Some things you see with your eyes and some things you see with your heart". In my heart is the belief that if we could show kids, teachers, and adults how to have fun with math, we could change their attitudes toward mathematics. If we can change attitudes, people will no longer hate and fear math, and maybe just maybe, they will learn the marvels that understanding mathematics can reveal.

And so, to remember another famous line from another movie, *Field of Dreams*, "If you build it, they will come." It is built, and to date approximately 14,000 children have come to visit the Math Center. The time has come to put this creation under the microscope. What experiences do visitors take with them after a visit to the Math Center? How do those experiences affect the tapestries of others' lives? How will what I learn affect the tapestry of my life, and how can I best weave mathematics into the story of the Math Center?

This paper is dedicated to my parents who never ever gave up on me, to my children who are my inspiration, endured very difficult times and continue to love and support my dreams, and to those “math nuts” who guided and continue to guide the Math Center and share the dream for our community and future!

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Chapter One: Go Figure

Mathematically speaking, the sum of success in building mathematical understanding has not been the product of making a difference in American mathematics education. Student performance in mathematics is still not making adequate gains in the United States. The Secretary-General of the Organisation for Economic Co-Operation and Development (OECD) presented the 2010 results of the Programme for International Student Assessment (PISA) in Washington, D.C. and reported, "…the U.S. drops below the OECD average in mathematics (rank 25)" (Gurria, 2010). Currently in the state of Missouri, only 52.7% of all students taking the Missouri Assessment Program (MAP) test are proficient in mathematics, and students statewide have not met the Adequate Yearly Progress (AYP) mandated by the state (Department of Elementary and Secondary Education [DESE], 2010). Not only is there inadequate growth in student performance in mathematics, but in addition, 67% to 75% of high school students leave high school with a divergent range of math anxiety ranging from a mild dislike of mathematics to math phobias (Wahl, 2005).

Currently in the United States, initiatives, programs, and grants for science, technology, engineering, and mathematic (STEM) improvements have grown exponentially. The Department of Education and the National Science Foundation have invested and spent billions of dollars toward improving mathematics education. However, the lack of progress in mathematics continues, and a pandemic of sorts has resulted. America is desperate for a cure as fears mount that without a solution, the United States will no longer be the global leader. As all eyes in America hone in on education, a plethora of implemented solutions have not improved the overall situation with mathematics education. The problems in mathematics education are not only systemic but also psychological, neurological, and societal in nature.

Background of the Study

Listen to the radio, television, or other adult conversations, and when the topic of mathematics arises, many adults proudly boast of their inadequacies in mathematics. In the 2007 report, *Rising Above the Gathering Storm*, Senator Bingham described the situation regarding attitudes towards mathematics, “Furthermore, many adults with whom students come in contact seemingly take pride in ‘never understanding’ or ‘never liking’ mathematics” (National Academies Press, 2007, p. 95). American society shuns citizens who cannot read. It is an embarrassment to be illiterate, but it is perfectly acceptable to be math illiterate because society holds different ideals for mathematics.

Neurologists and brain research have discovered through Magnetic Resonance Images (MRIs) the intricacies of how the brain learns mathematics. However, educators are not neurologists and thus are slow in the implementation of those findings. Sousa’s (2008) book on brain research and mathematics link positive emotions with the learning of mathematics while negative emotions inhibit the learning of mathematics. Therefore, negative attitudes towards mathematics and math anxiety interfere with the learning of the subject. As long as the acceptance of math illiteracy in American society exists, negative attitudes prevail, and the instruction of mathematics neglects to implement current brain research, improvement in student performance of mathematics will remain difficult.

Anxiety, negative attitudes, and psychological issues toward mathematics are, in part, probable explanations or reasons that math illiteracy continues to multiply.

However, who is affected by poor mathematical attitudes and math anxiety plays an important role in the lack of progress in raising student achievement in mathematics. Since 67% to 75% of adults suffer from some form of anxiety, then educators suffer from anxiety. A study conducted at the University of Chicago has shown that high math anxiety levels in female primary grade teachers have a negative effect on the levels of female primary students' math achievement (Beilock, Gunderson, Ramirez, & Levine, 2010).

Not only do attitude and anxiety negatively affect mathematical achievement, but an educator's mathematical content knowledge also affects student learning. A Harvard University research study suggested that the more content knowledge an educator had in mathematics, the more students enjoyed mathematics, the more in-depth the instruction, and the more effective the teacher was in responding to student questions (Hill et al., 2008). Therefore, teachers who have strong mathematical understandings have students who demonstrate higher levels of student achievement in mathematics.

The current acceptance of mathematical illiteracy in American society causes a societal problem (National Research Council, 1989). Negative attitudes and math anxiety have a negative effect on mathematical proficiency. Math anxiety can be passed to students. Students grow-up and some become educators with math anxiety. The math anxiety prevents the educator from being proficient at mathematics, which has caused the problems to improve mathematical understanding to become cyclic and contagious, requiring a different approach.

The researcher created an informal, educational, hands-on museum, called The Metamo4ic Math Center, to respond to and stop this cycle, providing "children of all ages" opportunities to improve their attitudes toward mathematics as well as provide exploratory experiences to discover how math works. The Math Center's design intended to bridge the formal education of mathematics, learning which occurred in a school setting, with informal education, learning which occurred in a museum setting during a visit or field trip experience. Researchers concluded that student participants retained content learned during a field trip visit one-year after the visit and students experienced improved attitudes (Farmer, Knapp, & Benton, 2007). Other studies demonstrated that field trips could result in cognitive or conceptual gains (Anderson & Lucas, 1997; Flexer & Borun, 1984; Orion & Hofstein, 1994). The Math Center made possible a place for children to practice and apply the mathematics taught in the classroom in a real life setting.

The Math Center was piloted as part of an after school extension program in a local school district during the 2006-2007 school year. After the pilot program, the concept expanded into a proto-type lab setting, which opened on September 8, 2007 in approximately 3,000 square feet of space in Ferguson, Missouri. Arranged into four large rooms, each room of the Math Center focused on a different strand of mathematics from the National Council Teachers of Mathematics (NCTM) and their connection to art and music. Since opening, over 14,000 students have visited the Math Center on field trip experiences.

The focus of this research was to study the effects of a two-hour visit to the Math Center on students, their teachers, and pre-service teachers from a math methods course taught through a local university. The research from this project intended to delineate what benefit(s) a visitor gained from a two-hour-field trip experience at the Math Center, an informal educational facility that employs hands-on interactive mathematical activities and exhibits in a museum setting. The researcher believes the definition of "benefit" must include cognitive, social, and affective factors that either positively or negatively influence the learning of mathematics.

Statement of Problem

Student achievement in mathematics, as measured by standardized testing, is not improving in this state or the nation. This study investigated math anxiety, attitudes towards math, and mathematical understandings of teachers and students who attended the program of a private nonprofit mathematical educational center. This center utilizes experiential learning in an informal educational setting in an attempt to decrease teacher and student math anxieties, improve negative attitudes, and build understanding towards teaching and learning mathematics.

Purpose of Study

The purpose of this mixed methods study was to determine changes in math anxiety levels and attitudes toward mathematics instruction and learning as well as mathematical understanding in students, their teachers, and pre-service teachers following a two-hour field trip visit to the Math Center. A secondary purpose of the study was to explore the experiences contained within a two-hour field trip visit to the prototype Math Center from the perspectives of students, teachers, and pre-service teachers. This study covered a time-period from January 2011 to May 2011. The pre-service teacher and student groups completed a pre, post, and post-post visit attitude survey and concept knowledge map. The teacher group and pre-service teacher group were interviewed one-week before the visit, one-week after the visit, and participated in a focus group interview one month post-visit. The in-service teachers were interviewed by the researcher; however, the pre-service teachers were interviewed by an independent evaluator as they were students of the researcher.

The quantitative data for this study were collected using an adapted Mathematics Anxiety Scale-Revised (MAS-R) survey instrument and were analyzed using Excel. The qualitative data were collected through interviews and a concept knowledge map that asked participants to map their answer to the question, “What is math?”

The independent variable of this study was the Math Center and the dependent variables were the perceived and tested mathematical abilities of the participants, the math anxiety level of the participants, the socio-economic level of the participants, and the pedagogical experience of the participants. The data from this study might provide instructional leaders with strategies on how to implement informal educational practices to improve student achievement in mathematics.

Research Questions and Hypotheses

This study investigated three questions.

Research Question 1. What changes do elementary students experience from a visit to the Metamo4ic Math Center, and do they lead to lowering math anxiety, improving attitudes towards mathematics, and/or an increase in mathematical understanding?

Hypothesis 1. Student participants in the Metamo4ic Math Center program will evidence a measurable gain in attitude towards mathematics instruction in their curriculum.

For example, students who visit the Math Center would be more likely to demonstrate a gain in positive attitudes on the post-visit MAS-R survey instrument than those students in the control group who do not visit the math center. These students would also be more likely to demonstrate a gain in positive attitudes on the post-visit administration of this instrument than the pre-visit administration of the instrument.

Null Hypothesis 1. Student participants in the Metamo4ic Math Center program will not evidence a measurable gain in attitude towards mathematics.

Hypothesis 2. Student participants in the Metamo4ic Math Center program will evidence a lessening of anxiety towards mathematics.

For example, students who visit the Math Center would be more likely to demonstrate a lessening of anxiety on the post-visit MAS-R survey instrument than those students in the control group who do not visit the Math Center. These students would also be more likely to demonstrate a lessening of anxiety on the post-visit administration of this instrument than the pre-visit administration of the instrument.

Null Hypothesis 2. Student participants in the Metamo4ic Math Center program will not evidence a lessening of anxiety towards mathematics.

Hypothesis 3. Student participants in the Metamo4ic Math Center program will evidence a measurable increase in mathematical understanding.

For example, students who visited the Math Center would be more likely to demonstrate more mathematical understanding based on the completion of the post-visit concept knowledge map than those participants in the control group who do not visit the Math Center. In addition, the concept knowledge maps completed pre-visit would have fewer positive affect words, mathematical concepts, and/or connectors as compared to the completed post-visit concept knowledge maps after the visit to the Math Center.

Null Hypothesis 3. Student participants in the Metamo4ic Math Center program will not evidence a measurable increase in mathematical understanding.

Research Question 2. What changes do in-service elementary teachers experience from a visit to the Metamo4ic Math Center, and do they lead to lowering math anxiety, improving attitudes towards mathematics, and/or an increase in mathematical understanding?

Hypothesis 4. In-service teacher participants in the Metamo4ic Math Center program will evidence a positive gain in attitude and lessening of anxiety towards mathematics.

For example, the classroom (in-service) teachers who bring the student participants to visit the Math Center would be more likely to demonstrate a lessening of anxiety on the post-visit MAS-R survey instrument than those in-service teachers in the control group who do not visit the Math Center. These in-service teachers would also be more likely to demonstrate a lessening of anxiety on the post-visit administration of this instrument than the pre-visit administration of the instrument.

Null Hypothesis 4. In-service teacher participants in the Metamo4ic Math Center program will not evidence a gain in attitude and lessening of anxiety towards mathematics.

Hypothesis 5. In-service teacher participants in the Metamo4ic Math Center program will evidence a measurable increase in mathematical understanding.

For example, the classroom (in-service) teachers who brought the student participants will demonstrate more connections on the post-visit concept knowledge map than the teachers in the control group who did not visit the Math Center. In addition, the concept knowledge maps completed pre-visit would have fewer positive affect words, mathematical concepts, and/or connectors as compared to the completed post-visit concept knowledge maps after the visit to the Math Center.

Null Hypothesis 5. In-service teacher participants in the Metamo4ic Math Center program will not evidence a measurable increase in mathematical understanding.

Research Question 3. What changes do pre-service elementary teachers experience from a visit to the Metamo4ic Math Center, and do they lead to lowering math anxiety, improving attitudes towards mathematics, and/or an increase in mathematical understanding?

Hypothesis 6. Pre-service teacher participants in the Metamo4ic Math Center program will evidence a positive gain in attitude and lessening of anxiety towards mathematics.

For example, the pre-service teachers who visit the Math Center would be more likely to demonstrate a lessening of anxiety on the post-visit MAS-R survey instrument than those pre-service teachers in the control group who do not visit the Math Center. These pre-service teachers would also be more likely to demonstrate a lessening of anxiety on the post-visit administration of this instrument than the pre-visit administration of the instrument.

Null Hypothesis 6. Pre-service teacher participants in the Metamo4ic Math Center program will not evidence a gain in attitude and lessening of anxiety towards mathematics.

Hypothesis 7. Pre-service teacher participants in the Metamo4ic Math Center program will evidence a measurable increase in mathematical understanding.

For example, the pre-service teachers will demonstrate more connections on the post-visit concept knowledge map than the pre-service teachers in the control group who did not visit the Math Center. In addition, the concept knowledge maps completed pre-visit would have fewer positive affect words, mathematical concepts, and/or connectors as compared to the completed post-visit concept knowledge maps after the visit to the Math Center.

Null Hypothesis 7. Pre-service teacher participants in the Metamo4ic Math Center program will not evidence a measurable increase in mathematical understanding.

Interviews. The purpose of the in-service and pre-service teacher interviews was to investigate the preparation, mechanics, and overall quality of the visit to the Metamo4ic Math Center. For example, it was important to know if the information sent prior to the trip was effective in helping the educator plan for the visit and if the Math Center was clean, organized, and conducive to learning. It was also important to know what the educators thought about making improvements to the programs at the Math Center. Please note from this point forward, The Metamo4ic Math Center will be referred to as the Math Center.

Definition of Terms

Best Practice. Best practice is a term normally associated with the law, medicine, engineering, or architecture. Taken from those fields and adapted into education best practice is defined as "…a shorthand emblem of serious, thoughtful, informed, responsible, state-of-the-art teaching" (Zemelman, Daniels, & Hyde, 2005, p. vi).

Concept Knowledge Map. A concept knowledge map is a word graph that represents and/or organizes knowledge. The graph is usually arranged by boxes or circles with words or symbols inside the boxes or circles that represent the idea or concept (Novak & Canas, 2008).

Constructivism. Hein states that constructivism is not new, but rather has evolved from the ideas of John Dewey as well as others (Hein, 1991). Hein and Alexander (1998) define constructivism as

> learning situations that require learners to use both their hands and minds to interact with the world: to manipulate, to experiment, to reach conclusions, to increase their understanding about the phenomena with which they are engaged. Constructivism also postulates that conclusions reached by the learner are not validated by some external standard of truth but only within the experience of the learner. (pp. 36-37)

Effective Teaching. Effective teaching is a method of teaching that develops mathematical proficiency in students over time (Kilpatrick, Swafford, & Findell, 2008).

Experientialism. Museum work revolves around the design of experiences to cause learning. The origin of experientialism is the Experiential Learning Theory, which is a blend of experiential learning from John Dewey, social psychology from Lewin, and

Piaget's work in cognitive development (Kolb, 1984). Kolb (1984) defines learning through Experiential learning as, "…the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" (p. 41).

Field Trip. A field trip is a field experience that occurs out of the school setting which has a short duration (Farmer et al., 2007) and can be more broadly defined as, "Out of school learning" (Braund, Reiss, Tunnicliffe, & Moussouri, 2004, p. 1).

Formal Education. Learning that occurs in the school-based setting (Falk, 2001).

Free-Choice Learning. The term, "free-choice" as defined by Falk (2001):

> *Free-choice learning* is a term that recognizes the unique characteristics of such learning: free-choice, nonsequential, self-paced, and voluntary. It also recognizes the socially constructed nature of learning—the interchange that goes on between the individual and his or her socialcultural *and* physical environments. The vast majority of learning that occurs outside of school involves free-choice learning—learning primarily driven by the unique intrinsic needs and interests of the learner. By contrast, the vast majority of the learning that occurs within formal education setting involves compulsory learning—learning driven by a predetermined set of requirements dictated by externally imposed authority. *Free-choice* thus emerges as a more descriptive, more accurate modifier for the term learning; it also has the advantage of being a neutral term, largely independent of the positive and negative biases that surround schooling (p. 7).

Informal Education. Informal education is learning that occurs outside of the school setting in places like museums, science centers, and the internet (Falk, 2001).

Falk argues that the term “informal” should be replaced with the term “free-choice” as there is, “…no convincing evidence that the fundamental processes of learning differ solely as a function of the physical setting” (Falk, 2001, p. 7).

Mathematics Anxiety Scale-Revised (MAS-R). A mathematics anxiety bidimensional scale developed by Bai, Wang, Pan, and Frey. The scale was developed to “…capture both positive and negative affects of the latent construct of mathematics anxiety. In addition, for an instrument to have adequate measurement efficiency, its test length must be optimized with desirable psychometric quality” (Bai, Wang, Pan, & Frey, 2009, p. 4).

Math Anxiety. The definition of math anxiety is multifaceted. It is an unpleasant emotional response to the subject; it is specific to mathematics; it has physical symptoms such as a nervous stomach, tiredness, and sweaty palms; it can interfere with the manipulation of numbers and solving mathematical problems; and it often leads to an avoidance of the subject (Beilock et al., 2010; Gresham, 2007).

Math Attitudes. Attitudes toward mathematics are considered part of the affect of mathematics. A one-size fits all definition of mathematical attitudes is not possible as attitudes are looked at one dimensionally, bi-dimensionally, or multi-dimensionally. Attitude may be positive or negative. Attitude is comprised by three verbs (multi-dimensionally): thinking, feelings, and resulting behaviors. A bidimensional attitude towards mathematics includes the pattern of beliefs and emotions associated with mathematics (Kislenko, 2006; Zan & DiMartino, 2007).

Mathematics. The origin of the word:

> Etymologically, mathematics means ‘something learned’. Its ultimate source was the Greek verb manthánein ‘learn’, which came from the same Indo-European base (*men-, *mon-, *mn- ‘think’) as produced English memory and mind. Its stem form math- served as a basis of a noun máthēma ‘science’, whose derived adjective mathēmatikós passed via Latin mathēmaticus and Old French mathematique into English as mathematic, now superseded by the contemporary mathematical (16th c.). Mathematics probably comes from French les mathématiques, a rendering of the Latin plural noun mathēmatica. From earliest times the notion of ‘science’ was bound up with that of ‘numerical reasoning’, and when mathematics reached English it was still being used for various scientific disciplines that involved geometrical calculation, such as astronomy and physics, but gradually over the centuries it has been narrowed down to a cover term for the abstract numerical sciences such as arithmetic, algebra, and geometry.
>
> The abbreviated form “maths” dates from the early 20th century, and the preferred American form “math” dates from the late 19th century.
>
> The original meaning of the word’s Greek ancestor is preserved in English polymath ‘person of wide learning’ (17th c.) (Mathematics Word History, 2011, p. 1).

Based on the origin of the word, the legend that Pythagoras, a famous ancient Greek mathematician, defined mathematics as a way of learning seems plausible. From a modern perspective, the definition of mathematics is more than a way to manipulate numbers. It “…is the science of patterns” (Zemelman et al., 2005).

Math Proficiency. Five interwoven and interdependent strands of: conceptual understanding—comprehension of mathematical concepts, operations, and relations, procedural fluency—skill in carrying out procedures flexibly, accurately, efficiently, and appropriately, strategic competence—ability to formulate, represent, and solve mathematical problems, adaptive reasoning—capacity for logical thought, reflection, explanation, and justification, and productive disposition—habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy. (Kilpatrick et al., 2008, p. 5)

Museum. There are many different types of museums. Institutions such as Science Centers, Natural History Museums, Art Museums, Aquatic Museums, and Transportation Museums are considered museums. A definition from Walhimer (2011), which encompassed all types is, "An organization in the service of society and its development, open to the public, which researches, communicates and exhibits things and ideas, for the purposes of education, study and enjoyment", (p. 1, para. 2).

Limitations

Sample Size. A limitation of this study was the sample size. The study included 113 elementary students, 41 pre-service teachers, and six in-service teachers. A larger sample size may have changed the results of this study.

Sample Demographics. A limitation of this study was the demographics of the participants. Although the control was a classroom in the same school and mirrored the socio-economic status, gender, and race of the treatment classroom, it was not an exact duplicate of the treatment group. Samples involved two school districts with similar demographics and three schools within those two districts. A blend of the demographics, which mirrored the demographics of the visitors the math center serviced, may have affected the results of this study. In addition, two of the participating treatment groups were not matched with a control group. If control groups existed, they may have affected the results of this study.

Sample Selection. A limitation of this study was the selection of the sample. Schools from throughout the area were invited to participate, but a limited number of responses were received. Therefore, had a more varied sample been used, the results of the study may have been different.

Curriculum. Another limitation to this study was the mathematics curriculum and math series used by each school. Although all followed the state Grade Level Expectations (GLEs), the results may have been different had each school implemented the same curriculum.

Participant Experience. Another limitation to this study was the experience level of each classroom instructor. The experience level of each teacher participant was not controlled. Therefore, the experience of each classroom instructor could affect the study.

Participant Participation. The original design of this study was modified to accommodate more participants to participate in the study. One district requested that their students receive the treatment at one time, which caused the elimination of the control group for the school in that district.

Researcher Bias. A limitation to this study was researcher bias. The researcher founded the Math Center. The researcher did employ the services of an independent evaluator to observe each field trip experience and participate in all interviews. Therefore, the results of the study may have been different had the entire study been performed by an independent evaluator. However, the researcher chose a previously validated instrument for the quantitative analysis to make the data more objective.

Participant Bias. A possible limitation to the validity of this study could be the absence of any costs to the participants other than providing their own transportation, which might bias them favorably toward the experience.

Administration of the Study Instruments. Another limitation to this study was the directions and instructions to the teacher participants on how to administer the MAS-R and Concept Knowledge Maps. Teacher participants were provided with instructions and PowerPoint presentations on the administration of the MAS-R inventory and the *Knowledge Concept Map*. Teacher participants were given a checklist to follow which detailed the dates and provided instructions specific to each school participating in the study yet outlined consistency in the administration and time intervals of the instruments. The instructions and directions for the administration of the instruments may not have been consistently followed thus affecting the results of the study.

Location. Another limitation to this study was the location. This study focused on schools and participants in one area of the United States, St. Louis County, Missouri. Had the study been conducted in another part of the country, the results could have been different. The administration of the instruments was completed at each participating school, but the classroom settings varied at each school participating in the study.

Replication. Another limitation to this study is the expense in replicating the study. The cost of museum exhibitions ranges between $75.00 and $550 per square foot (Walhimer, 2011). Although the Math Center cost was much lower than the norm, it would be costly to replicate.

Tornado Damage. During the study, a tornado severely damaged the building that housed the Math Center and caused it to cease daily operations. This affected the timely gathering of data, which may have affected the results of the study. Math Center services were redesigned to be delivered on location in schools and organizations. The control groups received their treatment through the redesigned delivery model.

Delimitations

This study, designed to evaluate a two-hour field trip visit to a Math Center and the effects the visit had on students, their teachers, and pre-service teachers, did not investigate how well the subject of mathematics lent itself to the informal educational setting. The effectiveness of mathematics in the informal educational setting is not directly relevant to the purpose of this study as this study examined the effectiveness of the field trip visit. This study did not investigate mathematics instruction in the formal educational setting. Instruction in the formal educational setting is a multi-faceted issue and is not feasible to this study although improvements to mathematics instruction were a reason for founding the Math Center.

Summary

Making gains in mathematical achievement in the United States as well as in the state of Missouri still eludes educational institutions. There have been a plethora of implemented strategies to correct the problem, but the lack of achievement remains. The problem is multifaceted, cyclic, and appears to begin and end with attitude and anxiety towards mathematics. This study investigated the effectiveness and exhibit design of a

Math Center designed to change attitudes as well as show visitors how math works. Until American views and attitudes change toward mathematics, improvement in mathematics education and student achievement in mathematics will continue to suffer.

Chapter Two: Building the Bridge

The Math Center is a prototype math museum designed to change attitudes towards mathematics and provide opportunities for visitors to become a part of math. At the time of its inception, the only other institution similar to it in the United States was the Gondreau Museum in Long Island, New York, which closed sometime in 2007. In 2008, a group of "interested parties" in New York expanded he idea from the Gondreau Museum into the Mo Math Museum, which is scheduled to open in Manhattan, New York in 2012 (Whitney, 2011). Although the Math Center and the Mo Math Museum have similar missions of changing attitudes through hands on math experiences for visitors, the way that each organization approached delivering the mission is different. This study explored visitor experiences during a two-hour field trip visit to the Math Center. The focus of the study was to determine the effects the Math Center had on elementary students, their teachers, and preservice elementary teachers. Literature from informal education; best practices in the instruction of mathematics; math anxiety; attitudes toward mathematics; how the brain learns; field trips; constructivism and experientialism make the connections that support this study.

If formal education is a body of knowledge on one side of an informational highway and informal education, a body of experiences, is located on the other side, then a bridge to connect the two together may provide a different way for children to cross into a new understanding of mathematics. The intended design of the Math Center provides positive experiences for children to connect mathematical instruction in the classroom to their schemata using their hands and minds. If the Math Center is the bridge that connects mathematical instruction in the formal and informal educational settings by accomplishing its mission to improve math attitudes and demonstrating to visitors how math works, then a literature review, which emulates bridge construction, needs to weld the research together to build the support for the bridge.

Piers support a bridge, and the piers of research that support the Math Center are informal education studies, research in best practices in mathematics instruction, math anxiety and attitudes toward mathematics studies, studies on how the brain learns, studies on field trips, and the educational theories of constructivism and experientialism. The review of research, which supports the Math Center, at the same time, will erode away at the body of knowledge, formal education.

On One Side of the Bridge, the Body of Knowledge - Mathematics in the Formal Educational Setting

The National Council of Teachers of Mathematics (NCTM) was the first educational organization in America to establish standards to guide instruction in schools (Zemelman et al., 2005). NCTM published works that addressed curriculum, evaluation, assessment, principles, and standards to guide the instruction and learning of mathematics in 1989, 1991, 1995, and 2000. Federal, state, and local agencies implemented these standards in the development of curriculum (Common Core State Standards, 2010; DESE, 2008). The last published work, *Principles and Standards for School Mathematics*, stated the standards developed for mathematics:

> reflects input and influence from many different sources. Educational research serves as a basis for many of the proposals and claims made throughout this document about what it is possible for students to learn about certain content areas at certain levels and under certain pedagogical conditions. The content and

> processes emphasized in *Principles and Standards* also reflect society's needs for mathematical literacy, past practice in mathematics education, and values and expectations held by teachers, mathematics educators, mathematicians, and the general public. (National Council of Teachers of Mathematics [NCTM], 2000, p. xii)

Best Practices for Math Instruction in the School. In its 2000 edition, the NCTM named six principles that "describe particular features of high-quality mathematics education" (p. 11). They are as follows:

1. *Equity.* Excellence in mathematics education requires equity--high expectations and strong support for all students**.**
2. *Curriculum.* A curriculum is more than a collection of activities: it must be coherent, focused on important mathematics, and well articulated across the grades.
3. *Teaching.* Effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well.
4. *Learning.* Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge.
5. *Assessment.* Assessment should support the learning of important mathematics and furnish useful information to both teachers and students.

6. *Technology*. Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning. (National Council of Teachers of Mathematics [NCTM], 2000, pp. 11-12)

The overarching idea of math instruction is for teachers to facilitate students to understand that mathematics is by its definition a way of learning. It encompasses many topics, but is a blend of patterns, concepts, and sets of ideas that interconnect to form dynamic relationships (Zemelman et al., 2005). An instructional task force from the United States Department of Education reported that there is no one instructional approach that works. However, the meta-analysis concluded teachers needed to know what a student understands and is able to do. Second, instruction needed to be constructed from a foundation of researched practices, and the instruction should reflect the needs of the students. Third, teachers needed to use a variety of instructional strategies and use the tools and approaches that best match the mathematical goals (Gersten et al., 2008).

The Final Report from the National Mathematics Advisory Panel stated several conclusions regarding instructional practice. First, there is no extenuating evidence that instruction should be entirely "student-centered" or "teacher directed". Second, the effects from Team Assisted Individualization (TAI), a cooperative learning approach, showed no significant change in performance in conceptual understanding or problem solving. Third, the results from research regarding the use of formative assessment have shown that formative assessment improved students' learning (National Mathematics Advisory Panel, 2008).

There are specific best practices that teachers need to implement to deliver quality instruction in the classroom. To support and challenge students, teachers follow standards through implementation of best practices (The Education Alliance, 2006). High quality teaching of mathematics requires a teacher's skills to deliver instruction using: inquiry that requires students to utilize what they know; focuses on critical thinking skills that requires students to synthesize and justify their conclusions; encourages students to question ideas; is aligned to curriculum, assessment, and high standards for student learning; and is continually reshaped through professional development (National Commission on Mathematics and Science Teaching for the 21st Century, 2000). In addition, high quality teaching builds on the diversity in student abilities and learning styles, goes beyond encouraging students to learn into insisting that they learn, and builds on students' strengths (National Commission on Mathematics and Science Teaching for the 21st Century, 2000).

Furner, Yahya, and Duffy (2005) presented 20 strategies and techniques (see Appendix A) for teachers to implement and effectively meet the needs of all learners. These strategies, described as *best practice,* were designed to engage English Language Learners (ELL), students receiving special services, students with short attention spans, as well as students in the regular classroom using what they referred to as a "multimodal approach" (p. 16). The implementation of these 20 strategies required deeper *cognitive demand*. Zurawsky (2006) stressed that to bring equity to mathematics, educators can no longer limit math education to students with college plans, as the workforce now requires the same mathematical capabilities as students who are college bound. Cognitive demand required students not only to access advanced mathematics courses but also to receive instruction that is not procedural but rather rich in conceptual understandings, which permit students to make strong mathematical conceptual connections. To achieve equity in education and bring the underserved population into mathematics to prepare them for the 21st-century job market requires cognitive demand not only in the higher grades but also in the early grades (Zurawsky, 2006).

Effective teaching produces mathematical proficiency, and "The effectiveness of mathematics teaching and learning is a function of teachers' knowledge and use of mathematical content, of teachers' attention to and work with students, and of students' engagement in and use of mathematical tasks" (Kilpatrick et al., 2008, pp. 9-10). Teacher expectations play a critical role in teacher effectiveness. Highly effective teachers of mathematics have high expectations for students. Kilpatrick et al. (2008) continued that a highly effective teacher is able to motivate students to want to learn mathematics. They are able to establish a community of learners between students who have different ability levels as well as different backgrounds. A teacher's expectations powerfully influences the mathematical activities selected for students, the level of the depth of inquiry with students, the processing time given to the students to respond as well as the encouragement students are given as they work through the learning process (Kilpatrick et al., 2008). A discussion of the lack of teacher effectiveness and the specific effects on student learning follows later in the review.

Instruction and instructional practices guide instruction and teaching strategies in mathematics, but what topics or areas of mathematics need to be instructed at the elementary level? NCTM developed specific K-12, the Content Standards – Number and Operations, Algebra, Geometry, Measurement, and Data Analysis and Probability that specifically detailed the mathematics that students should learn with the goal that all children should know algebra (National Council of Teachers of Mathematics [NCTM], 2000). Kilpatrick et al. (2008) described the math that elementary students should learn in preparation for the study of algebra:

> Students need to learn to make and interpret measurements and to engage in geometric reasoning. They also need to gather, describe, analyze, and interpret data and to use elementary concepts from probability. Instruction that emphasizes more than a single strand of proficiency has been shown to enhance students' learning about space and measure and shows considerable promise for helping students learn about data and chance. (p. 8)

Devlin (2001) suggested that learning mathematics has to be more than the "filling of a vessel" (p. 21). When students are actively engaged in the learning process through the element of play, they are more willing to take risks, explain their thinking, and build a greater understanding of abstract concepts (Young & Marroquin, 2008). Kilpatrick et al. (2008) found that when teachers engage students in learning tasks, manipulatives provide a connection between a student's informal knowledge and experience with mathematics. Additional research indicated that manipulatives, hands-on physical models, have positive learning outcomes when used in cooperative learning and exploratory and deductive learning activities. Manipulatives used in the regular classroom increase student understanding when used to demonstrate concepts and not procedures such as algorithms (Berkas & Pattison, 2007).

Best Practice Compared to Current Practice. What is happening in the mathematics classroom? The learning of mathematics often focuses on memorization more than understanding (Kilpatrick et al., 2008). A report from videotaped eighth-grade classrooms revealed the following teaching practices:

> (1) a review of previous material and homework, (2) a problem illustration by the teacher, (3) drill on low-level procedures that imitate those demonstrated by the teacher, (4) supervised seat work by students, often in isolation, (5) checking of seatwork problems, and (6) assignment of homework. In not one of the 81 videotaped U.S. classes did students construct a mathematical proof. (National Commission on Mathematics and Science Teaching for the 21st Century, 2000, p. 20)

This indicated that best practice instruction does not include student exploration or meaningful hands-on opportunities to understand the math.

Kilpatrick et al. (2008) compared the learning of reading and mathematics in schools and found that U.S. schools experience improvements in reading but not with mathematics. They suggested several factors that account for this difference. First, there is more remediation and interventions in reading than mathematics. Second, once students learn to read, the skills needed to deepen and/or broaden reading skills are not gained through instruction but rather practice. Reading is further developed and practiced throughout a student's life inside or outside of school. In addition, once children learn how to read, they use those skills to learn science, history, or mathematics. As mathematics is a continual building of more abstract ideas, it requires the instruction of more and more complex ideas from the teacher in order to be developed and understood by students. Third, students have a variety of exposure to literature outside school, and research showed that students who read at the 80th percentile spend 20 times more a day reading than students at the 20th percentile. This suggested that math instruction in the school may be more critical in a student's mathematical experience, and thus the consequences of good or poor instruction may have a greater impact on students' mathematical proficiency as compared to reading (Kilpatrick et al., 2008).

A RAND report suggested that those students who proficiently understand the math learned those mathematical practices outside of the school setting. This seemed to conflict with Kilpatrick et al. (2008) who suggested that school-based instruction comprised a large part of a student's mathematical understanding. However, when the lack of mathematical proficiency in the United States is taken into consideration as a whole, it must be tied in to teachers' mathematical proficiency. The RAND conclusion mirrored the current state of mathematical proficiency in this country and is based upon numerous studies which, "…show that many teachers in the United States lack adequate knowledge of mathematics for teaching mathematics" (RAND Mathematics Study Panel, 2003, p. xvi). Research continuously evidences that teachers' overall effectiveness and specifically a lack of mathematical proficiency and knowledge has a direct negative effect on student achievement in mathematics (Gersten et al., 2008; Hill et al.,2008; Kilpatrick et al., 2008; Marzano, 2007; National Commission on Mathematics and Science Teaching for the 21st Century, 2000; National Mathematics Advisory Panel, 2008; RAND Mathematics Study Panel, 2003).

Educator Mathematical Content Knowledge Weakens the Formal Educational Body of Knowledge. Educational research and brain research has concluded that students are capable of learning and understanding more mathematics than what is currently believed possible (Sousa, 2008; Zemelman et al., 2005). "Concepts are *built* by each person; understanding is created. Students have to explore many examples and talk about what they see and think, as well as hear explanations from the teacher" (Zemelman et al., 2005, p. 114). Researchers' analysis of teacher understanding revealed that teachers had a "thin" understanding of mathematics and the pedagogy necessary to teach it. This was true for elementary and secondary teachers regardless if they entered the field through traditional or alternative programs. The teachers were able to solve procedural problems, but were not able to explain their reasoning or how the procedures they employed worked. This was attributed to the fact that these teachers had been taught mathematics with the same methods within an institution that they themselves were trying to improve. A conclusion drawn from this research is that educators need to improve and increase their mathematical knowledge so they will obtain the skills to develop students' mathematical proficiency and thus support high quality math instruction (RAND Mathematics Study Panel, 2003). Teachers do not need the depth of knowledge as a mathematician, and further research is needed to determine what mathematics teachers need to know to be effective at building conceptual understanding in students (RAND Mathematics Study Panel, 2003).

Math In-A-Box Narrows the Curriculum and Weakens the Formal Educational Body of Knowledge. Curriculum in schools is more than a collection of activities as now standards-based education is the focus of curriculum design. In a report, (The Education Alliance, 2006) described standards-based mathematics as a framework that delineates skills, concepts, and knowledge that students are required to master. Currently 48 states have come together at the national level and collaborated to create the national Core Content State Standards (Common Core State Standards Initiative Process, 2010). As previously mentioned, the NCTM was the first organization to create standards which were written by professionals, based on research, and guided the presentation of mathematics with a challenging curriculum. The welcomed reception of the standards provided the impetus for the U.S. Department of Education to fund the development of standards for every school subject. Another standards movement began outside the teaching profession in businesses, state legislatures, and politicians, which undermined teachers' autonomy and professionalism as teachers were told what to teach and when to it by state departments of education, teaching moved into scripted manuals that ignored teachers' abilities (Zemelman et al., 2005). However, with these standards came accountability, and with accountability came high-stakes standardized testing to determine the success or failure of a school, and thus the focus of teaching is to teach to the test (Zemelman et al., 2005). When the teaching to test is the focus of education, the original professionally developed standards narrow to meet the demands of the test (Zemelman et al., 2005).

Assessment Practices Erode the Formal Educational Body of Knowledge. Learning mathematics actively engages students to build new knowledge. Assessment in mathematics supplies the teacher and the student with information on progress. For the teacher this means gathering data, examining the data for information on how to plan instruction, and then designing instruction for students (Long, 2007; Marzano, 2007). Marzano (2007) reported that formative assessment, assessment that forms and guides learning, is one of the most effective interventions ever reported. By having students record their progress, formative assessment provides each student with the knowledge of movement toward their learning goals.

Assessment, when used and designed properly, provides essential feedback to make instructional and curricular decisions (Marzano, 2007; The National Research Council, 1989). The National Research Council (1989) (NRC) discussed several issues with assessment and more specifically, the pervasive use of multiple-choice tests. The use of multiple-choice tests causes teachers to teach to the test; does not emphasize higher-order thinking; reinforces the "narrow image" of mathematics to students, teachers, and the public; provides only a snapshot of student performance instead of the big picture; and leads to lower student self-confidence in students with low-test scores. Instructional practices, teacher proficiency, and assessment play a large role in the current state of mathematical education; however, other factors add to the problem.

Lack of Brain-Based Education Weakens the Formal Educational Body of Knowledge. Mind, Brain, and Education Science (MBE) unites cognitive neuroscience, developmental psychology, and education into a new science. These fields of scientists learn from one another and "are on equal footing and contribute in identical parts to the new discipline's research, practice, and polices" (Tokuhama-Espinosa, 2011, para. 18). Five "well-established" concepts from all three fields comprise MBE:

1. *Human brains are as unique as faces*. Although the basic structure is the same, no two are identical. While there are general patterns of organization in how different people learn and which brain areas are involved, each brain is uniquely organized…Even identical twins leave the womb with physically distinct brains…the uniqueness of each brain explains why students learn in slightly different ways…

2. *All brains are not equal because context and ability influence learning*. Context includes the learning environment, motivation for the topic of new learning, and prior knowledge. Different people are born with different abilities, which they can improve upon or lose, depending on the learning context, including past experience and prior knowledge…
3. *The brain is changed by experience*. The brain is a complex, dynamic, and integrated system that is constantly changed by experience, though most of this change is evident only at a microscopic level. With rehearsal, these changes become permanent…In short, it is nearly impossible for the brain not to learn as experience…
4. *The brain is highly plastic*. Human brains have a high degree of plasticity and develop throughout the lifespan, though there are major limits on this plasticity, and these limits increase with age. One of the most influential findings of the 20th century was the discovery of the brain's plasticity. This discovery challenges the earlier belief in localization (i.e., that each brain area had a highly specific function that only that area could fulfill…neuroplasticity can explain why some people are able to recuperate skills thought to be lost due to injury…
5. *The brain connects new information to old*. Connecting new information to prior knowledge facilitates learning. We learn better and faster when we relate new information to things that we already know…there is no new learning without reference to the past. (Tokuhama-Espinosa, 2011, para. 5)

Some school districts have implemented math programs that require classroom teachers to be on the same lesson every day. What happens if students have not built a solid base of understanding before the introduction of new concepts? Brain-based learning demonstrates that students who do not have a solid foundation will continue to fail. Tokuhama-Espinosa (2011) continued:

> if we have a weak foundation, then it is irrelevant how sturdy the walls are, or how well built the roof is; the structure cannot be supported…Without a firm foundation in basic mathematical conceptualization…a student will have a lot of trouble moving on to build more complex conceptual understanding. (para. 6)

Math Anxiety and Negative Attitudes Erode the Formal Educational Body of Knowledge. Math anxiety is a "critical contributing problem" to the lack of mathematical achievement in the United States (Austin, Wadlington, & Bitner, 2001, p. 390). Students in the United States have moderate levels of procedural knowledge and low levels of conceptual understanding. This causes increases in math anxiety (Vinson, 2001). In fact, some teachers choose to teach at the elementary level because the mathematics requirement is minimal (Tobias, 1978). Most educators agree that elementary teachers with math anxiety would be best served to acknowledge their fears of mathematics and address those fears in "the best interest of their students" (Trujillo & Hadfield, 1999, p. 220). Teachers who display math anxiety often transfer this to their students (Austin et al., 2001; Beilock et al., 2010; Martinez, 1987). Teachers must assess their own anxiety level to determine the possibility of transmitting negative attitudes as well as anxiety to their students (Sovchik, 1996; Vinson, 2001). An explanation of math anxiety and its effects follows.

Pier One - Attitude towards Math and Math Anxiety.

Sometimes the terms “math anxiety” and “math attitudes” are used interchangeably. Fennema’s (1989) model includes both attitudes and anxiety as part of the effect on behaviors towards learning and have an effect on performance. Marsh and Tapia (2004) reported that research focused on attitudes toward mathematics has been more concerned with anxiety than the actual investigation of students’ attitudes towards mathematics, and suggested that the field of researchers attribute the poor performance of students with negative attitudes toward mathematics to anxiety. They reported that developed instruments mainly measured anxiety or the enjoyment of mathematics, and therefore, attributed the problems with achievement or performance in mathematics to anxiety rather than attitude, and that it is possible for students to have high aptitudes for mathematics and find mathematics unappealing or socially unacceptable. This distinction necessitates research on math anxiety and negative attitudes toward mathematics.

It Begins and Ends With Attitude. Attitude addresses how humans approach anything they do in life (Ashcraft & Kirk, 2001). Attitude is an opinion or general feeling about something, and attitudes are formed or changed by experiences with an object or subject and by interactions with others, such as family members, peers, and teachers (Tocci & Englehard, 1991). Studies and research have consistently concluded that attitude affects student achievement, and students’ attitudes directly influence their success in mathematics (Ashcraft & Kirk, 2001; Geist, 2010; Miller & Mitchell, 1994; Tocci & Englehard, 1991).

The National Research Council (1989) reported that an attitude generally held by the American public that it is socially acceptable to not be good at mathematics works against higher performance in mathematics. The National Academy of Science (2007) advanced the need to increase student interest in mathematics; however, this is hindered by adults who take pride in not liking math or not understanding mathematics. Public attitudes about math can develop from memories of unpleasant childhood experiences, and the most common memory of mathematics may be of an unsuccessful and unsatisfying experience in a mathematics course (National Research Council, 1989). Peer pressure on students who perform well in math adds to the socially unacceptable issues, and widespread fears of “new math” and rigid views of mathematics reinforce the public perception that math is difficult and only for those who are mathematically inclined (National Research Council, 1989).

Negative attitudes toward math can begin early in life as children with parents who have negative attitudes toward math may also negatively affect their children’s attitudes toward math (Geist, 2010; Tocci & Englehard, 1991). Geist (2010) stated that experiences from the surrounding environment and adults in the lives of children, from the time of birth, begin to form a child’s understanding of math. Geist stated that data supported poverty as a significant risk factor in a young child’s success in mathematics. In fact, a father’s educational level had a greater impact on children’s mathematical success while a mother’s positive attitude and encouragement toward mathematics was linked to the child’s positive attitude towards the subject.

Children do not begin school to seek out reasons to hate math, but nonetheless, students can develop negative attitudes toward math during the primary years where instructional practices such as timed tests and teacher-imposed methods run counterproductive to a child’s natural intuitive thinking processes (Popham, 2008;

Scarpello, 2007; Stodolsky, 1985). Children who enter school with positive attitudes toward math change to view math as boring work from these teacher imposed methods (Popham, 2008).

Other factors contribute to students developing negative attitudes towards mathematics. Gender differences in attitudes toward mathematics are significant after the fourth grade, and girls are more susceptible to negative attitudes to math (Geist, 2010; Tocci & Englehard, 1991). Several factors such as timed-tests and other high-stakes assessments, the socialization of females, and the myth that men are better at math than women are attributed to this difference (Geist, 2010; Malinksky, Ross, Pannells, & McJunkin, 2006; Tocci & Englehard, 1991). A student's beliefs or perceptions of his or her mathematical abilities contribute to students developing negative attitudes towards mathematics (Shobe, Brewin, & Carmack, 2005). Females tend to feel less confident about their performance in mathematics than males and report they do not enjoy mathematics as much as males, and these beliefs develop from teachers and parents who believe girls are successful in mathematics due to hard work while boys are believed to be talented in mathematics (Geist, 2010).

The consequences of negative attitudes are far reaching beyond the classroom. Attitude determines how long, or even if, a student will persist in studying mathematics (Bai et al., 2009). At the collegiate level, only about 1% of undergraduate students major in the field of mathematics, and from 1990 until 2000, a 10-year span when undergraduate enrollment in post-secondary institutions rose nine percent, those seeking degrees in mathematics fell nineteen percent (Marsh & Tapia, 2005). This may present a problem for the stability and future of our country, as fewer students are entering mathematics; even fewer are seeking advanced degrees in mathematics. To further demonstrate the severity of the issue, currently, half of the college graduates enrolled in advanced mathematic programs are not from the United States (Marsh & Tapia, 2005).

Negative Attitudes Can Lead to Math Anxiety. Ashcraft (2002) stated:

> U.S. culture abounds with attitudes that foster math anxiety: Math is thought to be inherently difficult (as Barbie dolls used to say, "Math class is hard"), aptitude is considered far more important than effort (Geary, 1994, chap.7), and being good at math is considered relatively unimportant, or even optional. (p. 181)

Definitions of mathematical anxiety describe it as more than a dislike of mathematics. Characterized in a number of ways it includes the following: (a) uneasiness when asked to perform mathematically; (b) avoidance of math classes until the last possible moment; (c) feelings of physical illness, faintness, dread, or panic; (d) inability to perform on a test; and (e) utilization of tutoring sessions that provide very little success (Ertekin, Dilmac, & Yazici, 2009; Miller & Mitchell, 1994; Vinson, 2001). Another definition attributes mathematical anxiety to feelings and tension that interfere with the manipulation of numbers and the solving of mathematical problems in both academic and real-life situations (Richardson & Suinn, 1972).

Studies support the assertion that mathematical anxiety is a subject-specific type of anxiety, which is different from test anxiety (Ashcraft, 2002; Beasley, Long, & Natali, 2001). Research has determined that there are different types of mathematical anxiety. According to Beasley et al. (2001), there are two different types of math anxiety, affective mathematics anxiety and cognitive mathematics anxiety. Affective anxiety is described as the emotional component with symptoms such as feelings of nervousness, tension, fear, and unpleasant physiological reactions while cognitive anxiety is described as worry with symptoms such as negative expectations about mathematical performance. Of the two types, only affective anxiety has shown a consistent negative relationship to mathematical achievement.

Often people who suffer from math anxiety have negative perceptions of their own math abilities. Ashcraft (2002) stated:

> Interestingly, math anxiety is only weakly related to overall intelligence. Moreover, the small correlation of -.17 between math anxiety and intelligence is probably inflated because IQ tests include quantitative items, on which individuals with math anxiety perform more poorly that those without math anxiety. The small correlation (-.06) supports this interpretation. (p. 182)

Since 67 to 75% of high school graduates leave high school with mild anxiety to full-blown math phobias (Wahl, 2005), and intelligence is not a determining factor of math anxiety, where, when, or how does this dilemma begin? Anxiety has its roots in elementary schools and then continues to grow exponentially through high school. Trujillo and Hadfield (1999) explored the mathematical experiences of pre-service elementary school teachers and identified commonalities between the pre-service teachers. All of the participants recalled struggling in elementary school except one pre-service teacher. Here is what the students who struggled reported about their school experiences:

> There was a lot of drill and repetition and no hands on…There were so many rules and a lot of memorization…There was so much pressure and only one right way…I felt isolated and alone when I didn’t understand…I was labeled a slow

> learner…I was too shy to ask questions because kids are mean when you don't understand…Everything was rushed and nobody wanted to take the time to teach me…One teacher can scare you and you carry that all through school. (Trujillo & Hadfield, 1999, p. 223)

The causes of math anxiety fall into three areas: environmental factors, intellectual factors, and personality factors. The environmental factor area includes negative experiences in the classroom, parent issues, insensitive teachers, mathematics instruction presented procedurally, and classrooms where the delivery of lessons was in lecture form. Intellectual factors included instruction, which was not aligned to learning styles, student's attitude, lack of persistence, self-doubt, lack of confidence in ability, and the perception that mathematics was not useful. Personality factors include reluctance to ask questions or participate in class due to shyness, low self-esteem, and the belief that mathematics is a male domain (Trujillo & Hadfield, 1999).

Pier Two - How the Brain Learns

Learning is an interactive process between the individual, the environment, and emotion with the result being long-term storage of information in the brain (Jensen, 2005; Sousa, 2008; Willis, 2010). Learning occurs as the result of information being gathered from our senses, processed in our memory system, and then stored at a level in the brain that is dependent upon the amount of times it is reused and the meaning it has to the individual who is learning it (Sousa, 2008).

Jensen (2005) described the brain as a work in progress, and the activities in which humans engage can actually change the mass and organization of the brain. Brain studies have shown that musicians have areas of their auditory cortex that are 5% larger than the general population. This brain reorganization is purposeful and formed from real-life use and disuse (Jensen, 2005).

Brain research is providing education with opportunities to link educational policies and practices into the ways that the brain processes information (Hinton, Miyamoto, & Della-Chiesa, 2008). All experiences shape the physical structures of our brain (Hinton et al., 2008; Jensen, 2005). Connections that are made from experiences are strengthened, weakened, or eliminated depending upon how often those connections are activated. Because brain research has scientifically confirmed that the brain develops through "dynamic and continuous" interactions between biology and experience, neuroscience provides the means with which to design instruction that is more effective (Hinton et al., 2008; Jensen, 2005). Neuroscience has also provided evidence that emotions are fundamental to learning. Since there are relationships between emotion and learning, neuroscience has confirmed the importance of positive learning environments and avoidance of negative experiences (Hardiman, 2010; Hinton et al., 2008; Jensen, 2005; Sousa, 2008; Tokuhama-Espinosa, 2011; Willis, 2010).

Willis (2010) discussed the Reticular Activating System (RAS) and its responsibility in receiving messages from sensory nerves in the eyes, nose, ears, mouth, skin, muscles, and organs. These messages are filtered through the RAS and are sent to the prefrontal cortex or are sent to the reflexive response centers. Emotional control on the part of the learner keeps the RAS filter open allowing the flow of information to the prefrontal cortex. Stress or feelings of being overwhelmed cause the brain to take control over learning, and what the learner remembers is no longer in the control of the learner (Willis, 2010).

Brain research has also revealed that developmental theories do not accurately represent a young child's ability to learn mathematics and underestimate a young child's ability with numerical understanding. Brain research has shown that all humans are born with intuitive mathematical ability (Hinton et al., 2008; Sousa, 2008). Humans as well as most animals are born with number sense or the ability to *subitize*, which is to understand the concept of 'one', 'two', and 'three' without counting. Subitizing allows animals to understand the difference between one or many enemies, a skill necessary to survive. "Because we are born with number sense, most of us have the potential to be a lot better at arithmetic and mathematics than we think" (Sousa, 2008, p. 11).

Learning-The Processing of Information. Neuroscience research revealed information is processed in three major brain networks, the recognition network, the strategic network, and the affective network (Hinton et al., 2008). The recognition network or the RAS receives information from the senses or the environment, and it classifies and transforms that information into knowledge (Willis, 2010). The strategic network develops the plan and goals while the affective network processes the emotions involved with the learning, stress, interest, and motivation. The emotional center or limbic system of the brain is located in the center of the brain and includes many areas of the brain (Hinton et al., 2008). Emotion causes the brain as well as other areas in the body to release chemicals (Jensen, 2005; Willis, 2010). These chemicals not only affect emotions but also stay in the body and continue to have an effect on emotion. This explains why once an emotion occurs, it lingers. Therefore, the emotional state has an impact on what is learned (Jensen, 2005).

In order to learn, learning activities must create new memory patterns. There are three types of memory systems: short-term memory, working memory, and long-term memory. Short term and working memory systems are temporary storage; short-term retains information from a few seconds to a few minutes while working memory may last for a few minutes to a few days (Hardiman, 2010). The working memory is able to hold more information as children develop, and reaches its total capacity around the age of 14. The length of time the working memory holds information also increases with age (Sousa, 2008). Information moves from temporary memory to long-term memory, or it fades away (Jensen, 2005; Sousa, 2008). Rehearsal, the practice and repetition of newly learned material, is the most important factor in determining how well information is remembered or learned (Sousa, 2008; Willis, 2010). The working memory will quickly store the information if it has survival value or attach it to a strong emotional experience (Sousa, 2008; Willis, 2010). If those two things are lacking or missing, then the working memory must connect the information with the learner's past experiences as long as the information makes sense and has meaning to the learner (Jensen, 2005; Sousa, 2008; Willis, 2010).

Sousa (2008) suggested that, as the formal educational setting is not an environment that naturally induces the survival mode or provides strong emotional experiences, the brain uses the back-up learning plan. The success of the back-up plan depends on the brain being able to answer "yes" to two questions: (1) "Does this make sense?" From previous experiences, can the learner understand the mathematical content? Mathematical content that does not fit into a learner's schemata is difficult to transfer to long-term memory; and (2) "Does it have meaning?" Mathematical content must have meaning for the learner to recognize a purpose for it to be remembered. If a learner does not recognize the mathematic instruction as relevant, the chances that the learning will be stored in long-term memory decrease (Sousa, 2008).

Falk and Dierking (2002), researchers in the informal educational setting, reported:

> the general process of learning is comparable in all humans…learning is a uniquely individual, dare we say idiosyncratic, event. No two people ever learn exactly the same thing in quite the same way. The key to understanding this irony revolves around context, a fact that was either missed or avoided for nearly a hundred years. (p. 35)

They concluded that human knowledge is constructed, and it is not stored as collection but in "bits and pieces" that are put together on an as-needed basis. The construction of this knowledge connects to social, cultural, and physical contexts, and learning is seldom a spontaneous event, but rather a process of accumulating experiences (Falk & Dierking, 2002).

Therefore, the design of learning in the informal educational setting is to produce emotional and sensory experiences (Caban, Scott, & Swieca, 2000). However, the design of learning in the informal setting must take into account that the visitor, learner, chooses what he or she will learn unlike the school setting where learning is prescribed (Falk & Dierking, 2002). If an exhibit does not gain the attention of the learner, the learner moves to another exhibit or activity. The most remembered learning engages the emotions, and a design that intensifies the emotion or the senses increases the educational value (Caban et al., 2000).

Brain hemisphericity refers to how the brain processes information from its two hemispheres and is used to describe functions of the left-brain and right brain (Jensen, 2005). The left-brain generally operates in a sequential, detailed-oriented, analytic, and symbolic fashion while the right brain is wholistic, random, visual, and spatial (Jensen, 2005; Wahl, 2005). People do have preferences, but the experiences the brain encounters reorganize the brain and may not necessarily follow the functions associated with right brain and left-brain thinking generalizations, and therefore to label learning as left-brain or right brain is obsolete as the whole brain is involved in the learning process (Jensen, 2005).

Learning styles refer to how a person prefers to interact and engage in learning situations. Learning styles include: (a) auditory, visual, and/or kinesthetic input, (b) brain hemisphericity, (c) multiple intelligences, and (d) personality styles (Wahl, 2005). Since the instruction of mathematics has been mainly procedural and sequential (left-brained), implemented strategies should meet the needs of many different learners. This will also make math instruction more interesting and motivate students to learn (Sousa, 2008). Wahl (2005) suggested the inclusion of many approaches from different learning styles has a positive effect on improving math anxiety and attitudes.

Pier Three - Learning Theories

The NCTM Principles and Standards guide educators to provide deep understanding of mathematical concepts and engage students to build knowledge from experience and prior knowledge. Brain research indicates that learning must be meaningful, practiced, and in an environment that produces positive emotions. The constructivist and experiential learning theories support this type of learning (Hein &

Alexander, 1998). These theories bridge how humans learn mathematics, learn in the classroom, and learn in the museum setting.

Combining Experience, Perception, Cognition, and Behavior. The Experiential Learning Theory (ELT) originated with the research of Dave Kolb and emphasizes that experience plays a critical role in the learning process as it combines experience, perception, cognition, and behavior (Kolb, Boyatzis, & Mainemelis, 2000). The theory includes two related modes of grasping experience, Concrete Experience and Abstract Conceptualization, and two other related modes of transforming experience, Reflective Observation and Active Experimentation. The theory is a four-stage cycle of concrete experiences that cause observations and reflections in the learner. In the next stage, the reflections are assimilated; in the third stage, abstract concepts are formed; and in the fourth stage, the learner decides how to apply or test the concept in new situations (Kolb et al., 2000).

Four learning styles correspond to the stages of the ELT. These learning styles describe abilities within the learner. The abilities are direct opposites of one another in which the learner must choose which abilities to use in each specific learning situation. The learner bases his or her choices due to hereditary factors, past experiences, or upon the current environment. The four learning styles are identified as Diverging, Assimilating, Converging, and Accommodating (Kolb et al., 2000).

Eyler (2009) suggested that experiential education based upon experiential learning brings students out of the classroom and helps students to "bridge classroom study and life in the world and to transform inert knowledge into knowledge-in-use…It rests on theories of experiential learning, a process whereby the learner interacts with the world and integrates new learning into old constructs" (p. 24). Experiential education leads to more powerful academic learning and assists students to achieve intellectual goals. Experiences outside the classroom can bring about deeper understanding than through classroom instruction alone, can bring about critical thinking applications, and bring about the application of knowledge learned in the classroom (Eyler, 2009).

A formal setting alone does not prepare students to use what has been learned. Tests do not align to real-life, as life has no script that indicates the information students need to recognize and apply. Students need to recognize when what they have learned might be useful, otherwise, their understanding is incomplete and will not transfer to new situations. Eyler (2009) continued:

> Recall and reproduction of material taught in the classroom do not constitute understanding. For knowledge to be usable, it has to be acquired in a situation. Otherwise, it is segregated from experience and unlikely to be remembered or transferred to new experiences. Well-understood material can be retrieved from memory and used in new situations because it is linked with multiple experiences and examples and not isolated from other experience and knowledge. (pp. 26-27)

Individually and Socially Constructing Meaning. Van De Walle (2004) described constructivism as a theory of learning where the individual learner builds knowledge as the learner actively participates in the development of his or her own understanding. Constructivism's development is rooted in the theories of Piaget and Vygotsky (Shirvani, 2009). Cognitive constructivism refers to the learner constructing knowledge through a personal process while social constructivism refers to the process of learning, constructing knowledge, through social interactions with the teacher or other students (Powell & Kalina, 2009).

Powell and Kalina (2009) stated, “Cognitive constructivism came directly from Piaget’s work. Piaget’s theory of cognitive development proposes that humans cannot be given information, which they immediately understand and use; instead, humans must construct their own knowledge” (p. 242). Piaget’s research identified four stages of development: sensorimotor, preoperational, concrete operational, and formal operational (Ojose, 2008). Understanding Piaget’s stages of development and his theory of equilibration, where students resolve conflicts of new knowledge with that of current schema, are necessary for teachers to understand how to facilitate students in gaining knowledge at the appropriate rate for each individual student (Powell & Kalina, 2009; Shirvani, 2009).

Social constructivism was born from the research of Vygotsky (1997). Vygotsky believed that through social interaction students would build their own knowledge (Shirvani, 2009). Social constructivism is based on the social interactions a student experiences in the classroom and is integrated with the student’s critical thinking processes. Cooperative learning is a component of social constructivism and students need group projects or other activities that assist them in creating relationships that affect what they learn (Powell & Kalina, 2009). Mann (1999) stated, “The core of Vygotsky’s work examined human beings as meaning makers” (p. 341). Vygotsky’s research focused on children acquiring speech, the effects the acquisition of speech has on a children’s behavior, and how children utilize speech to manage their activities (Mann, 1999). Vygotsky (1997) said,

> We can formulate the general law of cultural development as follows: every function in the cultural development of the child appears on the stage twice, in two planes, first, the social, then the psychological, first between people as intermental [interpsychological] category, then within the child as an intramental [intrapsychological] category. This pertains to voluntary attention, to logical memory, to the formation of concepts, and to the development of will. (p. 106)

Theories of experiential learning and constructivism unite mathematics and learning uniquely in the informal setting. A constructivist epistemology is also well suited for the mathematics classroom, as it promotes a positive learning climate, engages learners to discover new concepts, and helps learners to improve the comprehension of mathematical concepts (Shirvani, 2009). Hein (1991) stated, “The principles of constructivism, increasingly influential in the organization of classrooms and curricula in schools, can be applied to learning in museums” (p. 20). Museum visits are experiential by nature, and thus mathematical experiences created in the informal setting initiate a process of transforming the museum experience to knowledge by employing students to use what they have learned.

Pier Four – Field Trip Experiences

Field trips contribute to student learning in the following six different ways: 1) Improve development and integration of concepts; 2) Extend and provides authentic practical work; 3) Provide access to rare material; 4) Improve attitudes toward the subject which stimulates further learning; 5) Develop personal development and responsibility; 6) Increase socialization (Braund, Reiss, Tunnicliffe, & Moussouri, 2004).

Braund et al. (2004) reported that students spend approximately two-thirds of their lives away from school, and overall educators pay little attention to the influence out of school learning has on students' beliefs, attitudes, and motivation to learn or on students' knowledge and understandings. Learning experiences in museums, science centers, botanical gardens, etc., are very different from that of formal schooling, which can be irrelevant, boring, and not prepare students to step into the 21st Century (Braund et al., 2004). Researchers concluded that student participants retained content learned during a field trip visit one-year after the visit and students experienced improved attitudes (Farmer et al., 2007). Other studies demonstrated that field trips could result in cognitive or conceptual gains (Anderson & Lucas, 1997; Flexer & Borun, 1984; Orion & Hofstein, 1994). Field trips align with the teacher's objectives of meeting a curriculum goal and improving student interest and motivation (Kisiel, 2005). When examining how field trips are conducted, research demonstrates that field trips are often not effectively implemented to yield the maximum conceptual or affective learning (Cox-Petersen & Pfaffinger, 1998).

Enhancing the Effectiveness of Field Trips. Dewitt and Osborne (2007) suggested that teachers improve the effectiveness of field trips visits by 1) becoming familiar with the setting before the trip; 2) orienting the students to the setting and clarifying the learning objectives; 3) implementing pre-visit lessons or activities aligned with curriculum goals; 4) allowing time for the students to explore and discover during the visit; 5) planning activities that support the curriculum and take advantage of the setting; and 6) implementing post-visit lessons and activities that reinforce the field trip visit.

The Framework for Museum Practice (FMP) was developed by Dewitt and Osborne (2007) to support teacher practices on school field trips. It is a "set of principles, distilled from research, scholarship, and practice, which could improve the educational effectiveness of class trips to museums and science centres, and so support the learning goals teachers and museum educators have for such experiences. (p. 688) The principles of the framework follow:

Principle 1: Adopt the perspective of the teacher – Develop resources that meet the needs of teachers' goals and objectives

Principle 2: Provide structure – Resources should connect the before, during, and after visit

a. Reduce the "novelty effect" by providing resources to support a pre-visit orientation

b. Reinforce the learning experience by providing resources after the visit to support the experience in the classroom

Principle 3: Encourage joint productive activity – Encourage students to work with one another and the teacher towards an end product

a. Activity should engage students, teachers, and adults to think together and build knowledge

b. Activity should evoke curiosity and interest

c. Activity should provide choice and control

d. Activity should cognitively challenge and engage students

e. Activity should be personally meaningful and allow the students to draw on their experiences

> Principle 4: Support dialogue, literacy, and/or research skills – Develop resources to extend the learning across other content areas. (Dewitt & Osborne, 2007, pp. 689-690)

Communication between museums and visiting schools influences the educational potential of the visit (Falk & Dierking, 2000). The higher the quality of communication, the better the visit is for both the students and the museum (Melber & Abraham, 2002). The key to success of field trips depends on the teacher's ability to organize, sequence, focus, and evaluate the field trip visit for the needs of the students (Tal & Steiner, 2006). In the museum, museum educators need to consider school curriculum when developing and designing programs and exhibits (Tal & Steiner, 2006). Tran (2007) stated that a failure of museum educators to utilize teachers as partners but rather as managers of time and discipline resulted in their lack of participation when on field trip visits. Tal and Steiner (2006) noted that complaints by teachers relating to lack of information about services and expectations combined with museum educators' concerns as to lack of teacher involvement in field trips must be addressed by both museum educators and teachers with the use of clear communication in order to ensure optimum educational opportunities.

Museum research includes many studies on conversations that occur in the museum between visitors (Falk & Dierking, 2000). Braund et al. (2004) summarized conversations between students and adult chaperones and concluded that the adults accompanying students on a field trip positively affect the quality of the interaction as there is more talk about features which include more knowledge. Adult chaperones concentrate more on managing and social aspects than do relatives or teachers. Parent agendas can ruin the students' enjoyment while teachers do not guarantee a higher quality of interaction.

The discussion of the learning mathematics in the formal setting concludes, and a discussion of learning in the museum follows.

On the Other Side of the Bridge, the Body of Experiences – Learning in the Informal Setting

Learning in the informal setting requires an explanation of key components that include the commonalities of museums, science centers, zoos, botanical gardens, etc; the application of learning theories in museums; learning in the museum; best practices; the use of manipulatives in mathematics; and exhibits and exhibit design.

The Museum. Just as different institutions compose the body of the formal setting, different institutions compose the body of the informal setting. Many people commonly refer to these institutions as museums. What exactly is a museum?

Boyer (1999) stated the word "museum" evolved from the word, "muse" which the ancient Greeks associated with nine muses who presided over song, poetry, and the arts and sciences, and thus, education. He continued, "In the ancient world, a museum was both a 'place of the muses' and a place for scholarship and learning, as in the Museum of Alexandria founded during the third century BC" (Boyer, 1999, p. 26). A visit to the American Association of Museum's (AAM) Website provides many different meanings for the word museum. Listed on the website from the federal government in the Museum and Library Services Act was this definition:

> A public or private nonprofit agency or institution organized on a permanent basis for essentially educational or aesthetic purposes, which, utilizing a professional

staff, owns or utilizes tangible objects, cares for them, and exhibits them to the public on a regular basis. (AAM, 2010, para. 2)

Today, there are thousands of museums, and many of them look and operate much differently than they did 100 years ago (Boyer, 1999). Although not called museums, other institutions do meet the museum definitions as they provide a place for learning, are organized for educational purposes, operate with a professional staff, utilize objects, and exhibit them to the public on a regular basis. Among the organizations considered museums but not called museums are aquariums, planetariums, zoos, botanical gardens, science centers, technology centers, and even amusement parks (McClean, 1993).

The Application of Learning Theories in the Museum. Hein and Alexander (1998) proposed that "educational theory" in museums is composed of a theory of knowledge, a theory of learning, and a theory of teaching. Theories of knowledge exist on a continuum between opposite positions between realism, the "real" world exists out there, and idealism, knowledge exists only in the individual mind. Learning theories exist based on what is termed passive learning where the learner absorbs information incrementally and active learning in which the learner constructs knowledge through participation. These theories combine to form four different domains that draw from a theory of knowledge and a theory of learning. The first, Expository-Didactic Education in museums presents collections and/or objects in chronological order, sequentially, or arranged by classification. The second, Stimulus-Response Education reinforces behavior such as pushing a button, lifting a flap, or touching a button that is rewarded with a positive response. The third, Discovery Education is learning through doing, and includes experiments or role-playing, and the fourth, Constructivism allows the learner to connect with objects through activities and social interactions through their life experiences (Hein & Alexander, 1998).

Hein (1991) proposed that constructivism is not a new fad but rather a new acceptance of core ideas previously expressed by John Dewey and others. He discussed the acceptance of the constructivist theory in museum education and that museum educators would need to recognize that there is no such thing as knowledge independent of the learner but only knowledge that the learner constructed. Hein (1998) stated that as museums and science centers implement constructivism into program and exhibit design,

> constructivist theory argues that in any discussion of teaching and learning, the focus needs to be on the *learner*, not on the subject to be learned. For museums, this translates into the dictum that we need to focus on the visitor, not the content of the museum. (p. 78)

Learning in Museums. Miles (2002) stated, “Learning is essentially a creative process, and the burden of it is always upon the learner” (p. 38). He explained teachers cannot make learning occur, teachers can stop learning from happening, and learning happens as it grows from a learner’s understanding. Hein and Alexander (1998) concluded that museum research indicated that museums excel at providing experiential, thought-provoking, and problem-solving learning experiences that are profound, enduring, and sometimes life changing for visitors. Learning in the museum causes a change in the visitor’s knowledge, skills, beliefs, feelings, and attitudes (Hein & Alexander, 1998).

McClean (1993) suggested that learning in museums is formal and intensive while still being personal, self-paced, and exploratory. Falk and Dierking (2000) suggested that researchers have utilized “flawed tools” to evaluate learning in a museum. Learning in a museum has been compared to traditional learning models like the transmission-absorption model, which suggests that learning in museums should be like learning in schools. In order to compare learning in a museum to the model of learning in a classroom, the exhibit takes the role of the lesson and the visitor assumes the role of the student. The lesson (exhibit) is presented, and the students (visitors) will learn. This model does not work in museums or in schools (Falk & Dierking, 2000). Learning in the museum is difficult to define because learning is both “a process and a product, a verb and a noun” (Falk & Dierking, 2000, p. 9). This presents a dilemma, and many social scientists circumnavigate this issue by identifying various types of learning such as sensory learning or learning that occurs in a classroom. Learning in the museum needs to be thought of as holistic and “as a series of related and overlapping processes” (Falk & Dierking, 2000, p. 9).

Falk and Dierking (2000) explained learning as it occurs in a museum based on years of research through development of a Contextual Model of Learning which, “involves three overlapping contexts: the *personal*, the *sociocultural*, and the *physical*. Learning is the process/product of the interactions between these three contexts” (p. 10). After ten years of working with this model, Falk and Dierking (2002) added another dimension to the model, *time*. The addition of time to the model augments the definition of learning to become, “the never-ending integration and interaction of these three contexts over time in order to make meaning” (p. 11). When trying to understand learning in the museum, one must understand that visitors bring their own personal experiences and knowledge into the museum, but leave with the seeds of knowledge that require further experiences and cultivation (Falk & Dierking, 2000). Hein and Alexander (1998) confirmed that previous knowledge, attitudes, and interests as well as social interactions within the museum impact how visitors make meaning from the museum experience.

Standards and Best Practices in Museums. Museum professionals under the umbrella of the AAM created standards and practices to guide museum operations. The standards are “generally accepted levels that all museums are expected to achieve. Best practices are commendable actions and philosophies that demonstrate an awareness of standards, solve problems and can be replicated” (American Assiociation of Museums Standards and Best Practices, 2011). The AAM worked to create the standards and best practices for accreditation purposes; however, they apply to all museums regardless if they are accredited or members of the AAM.

The core of National Standards and Best Practices for U.S. Museums on the AAM website, contain seven areas of best practices and standards for excellence in U.S. museums. Standard 5, Education & Interpretation, states eight specific characteristics:

5.1 The museum clearly states its overall educational goals, philosophy, and messages, and demonstrates that its activities are in alignment with them.

5.2 The museum understands the characteristics and needs of its existing and potential audiences and uses this understanding to inform its interpretation.

5.3 The museum’s interpretive content is based on appropriate research.

5.4 Museums conducting primary research do so according to scholarly standards.

5.5 The museum uses techniques, technologies, and methods appropriate to its educational goals, content, audiences, and resources.

5.6 The museum presents accurate and appropriate content for each of its audiences.

5.7 The museum demonstrates consistent high quality in its interpretive activities.

5.8 The museum assesses the effectiveness of its interpretive activities and uses those results to plan and improve its activities. (AAM, 2007, p. 1)

Best practices drives the learning in museums like learning in the classroom. Using manipulatives in the mathematics classroom improves student understanding of mathematics. A discussion on the use of manipulatives in mathematics as they would serve as objects in the museum setting follows.

Using Hands-On Manipulatives in Mathematics. Mathematical experiences that incorporate the use of manipulatives help students to understand mathematical concepts and how to apply those math concepts in other situations (Kennedy, 1986; Moyer, 2001). Manipulatives are materials or objects that can be touched, moved, or rearranged to represent abstract mathematical concepts or ideas that engage several senses (Kennedy, 1986; Moyer, 2001). Experiences with manipulatives decrease as the grade level increases (Stewart, 2003). A study suggested that the decrease in the use of manipulatives occurred for several reasons. Educators viewed manipulatives as toys and believed the use of manipulatives was not appropriate for older students, and educators did not know how to use the manipulatives in mathematics instruction (Tooke, Hyatt, Leigh, Snyder, & Borda, 1992).

Freer Weiss (2005), Moyer (2001), and Witzel, Mercer, and Miller (2003) found that the use of manipulatives is an effective learning tool to increase students' conceptual understanding of mathematics. Freer Weiss (2005), Moyer (2001), and Vinson (2001) stated their findings that manipulatives reduced math anxiety for elementary and middle school students and for pre-service teachers in math methods classes. In conclusion, research has shown that manipulatives improve understanding. Manipulatives are objects or things, and museums, "exhibit things and ideas, for the purposes of education, study and enjoyment" (Walhimer, 2011, p. 1 para. 2). Therefore, manipulatives are included in museum exhibits and exhibit design.

Exhibitions, Exhibits, and Exhibit Design. Miles (2002) suggested that all exhibits are educational by their nature and that the educative component may not be the most important objective within the variety of the many different exhibits types. He defined an exhibition as a display for human inspection that raises people to be moved or emotionally touched. When exhibits do not move or touch the visitor, the visitor will have a tendency to feel disappointed (Miles, 2002). An effective educational exhibit will construct a story line or theme for a target audience, and the story-line or theme will determine, "the objects displayed and not the other way round" (Miles, 2002, p. 10). Caban et al. (2000) further stated that exhibits can communicate the story with words and emotion, but the emotional and sensory effectiveness is intensified by the manipulation of the design elements, which in turn cements the educational value and learning potential of the story.

The design of the exhibit does affect the visitor. In most galleries, 80% of visitors will enter and move to the right. “Good design draws the visitor in, engages all the senses, and compels the visitor to investigate the topic at hand” (Falk & Dierking, 2000, p. 123). A blend of space, shape, mass, color, texture, pattern, unity and variety, balance, rhythm, emphasis, proportion, and scale make exhibits attractive to a visitor. In addition to these traditional elements, good design also includes sounds, smells, plants, animals, and people (McClean, 1993). However, exhibits require a quality idea as well as quality design (Falk & Dierking, 2000).

A study of exhibit designers concluded the three most important skills or attributes in design practice are communication skills, technical skills, and creative thinking (Caban et al., 2000). Carliner’s (2003) research illuminated four concepts used by exhibit designers. The first concept was to immerse the visitor in the story. The second concept was to divide complex topics into a limited number of key themes. Most exhibits studied in Carliner’s (2003) study were subdivided into fewer than five themes. This goal of the subdivision into themes is to provide the visitor with better recollection of the insights from the exhibit. The third concept is to layer the content of the exhibit. Layering sprinkles the learning around the exhibit, and the goal is for the visitor to explore as he or she would like and be able to leave satisfied that they learned a complete topic. Designing the labels, signs that provide explanations about the exhibit, can be tiered. Introductions, titles on the exhibit, need to be readable by the visitor from several feet away. Theme labels introduce key concepts that consist of a heading, contain a limited amount of text, may include a picture or diagram, and need to be readable by the visitor from a few feet away. Finally, there are object labels, which label the object.

Text on an object label is the longest of all three labels, is small, and the visitor must stand close to read it. The last concept Carliner (2003) referred to was “skimmability.” All visitors are different ages and have different backgrounds. The language used must not assume the visitor understands the subject matter, and since visitors read labels while standing, the designer must accommodate the visitor so that labels can be read quickly (Carliner, 2003). In fact, visitors are more likely to read three 50-word labels rather than one 150-word label containing the same text (Falk & Dierking, 2000). It is the goal of the exhibit design to have visitors read the labels as the more the visitor reads labels, the more likely the visitor will investigate further (Falk & Dierking, 2000).

Carliner’s (2003) research revealed that museum design should keep visitors wanting to go around the next corner and continue to explore. Layouts of exhibits may be created from a specific point of entry or hub design while other layouts let visitors enter from any point. Design may include controlled approaches, as the sequence of the design is critical to the telling of the story. Order and format need to cause the visitor to advance as they cannot easily correct errors or backtrack to other exhibits (Miles, 2002). Architectural elements and or interior design of the building design may be used as part of the design elements of an exhibit. For example, flooring may simulate a sidewalk. The creation of mood and ambiance in an exhibit is obtained by manipulating light levels. Particular objects are selected to catch attention or are specifically placed in an exhibit to be seen from other parts of the exhibit. Including seating in specific areas provides visitors a chance to rest to avoid fatigue. Design should also consider traffic patterns so that the placement of more popular temporary exhibits will cause visitors to pass by other permanent areas (Carliner, 2003).

In conclusion, Miles (2002) listed the "overarching principles" of museum design that focus the designer on the learner's needs. The first principle is that the learner must know what is happening. The learner must be oriented and understand that the main teaching points are within grasp as well as worth learning. The second principle is that the learner must know what to do. The exhibit must clearly signal the expectations for the learner to understand. The third principle flows from the articulation of the first two principles. The visitor knows what is going on and what to do, but the visitor must want to do it. Visitors cannot be made to do things, but design can encourage the visitor to attempt what is asked. The fourth principle emphasizes that the visitor must be provided with the opportunity to try to do what has been asked. If the visitor chooses to take the opportunity to try, the visitor's attempts should not be frustrated by the design (Miles, 2002).

Effective museum design must be implemented for learning to occur in the museum, as effective lesson planning must be employed for learning to occur in the classroom. As both formal education and informal education exist for learning, there are other connections, collaborations, and relationships that need to be built between the two institutions.

Cementing the Formal and Informal Settings Together

Education reform has directed much effort to improving science (which includes math) instruction and to increasing student learning by moving away from rote memorization to hands-on experiences, networked technologies, and student-developed investigations (Lebeau, Gyamfi, Wizevish, & Koster, 2001). Lebeau et al. (2001) stated that reform efforts have encouraged collaboration and partnerships with corporations, universities, and cultural organizations, and "most free-choice science learning environments are hallmarks of experiential learning, exploration, and discovery" (p. 133). Frankel (2001) discussed the contribution of the informal setting in stimulating disinterested students and re-exciting high performing students during field trip experiences and the need for the free-choice sector to become a "proactive player" in making public policy in educational reforms. She proposed an agenda to document progress through research and studies, join arms to demonstrate that the free-choice sector as a necessary resource for well-educated citizens, prioritize the importance of free-choice education to formal education, and maintain public policy by developing connections in establishing a core policy.

Lebeau et al. (2001) suggested that the distinction between informal and formal education has been a barrier to building collaborative efforts between the two institutions. A set of principles to connect the informal and formal settings was created to make the free-choice visit more than an isolated field trip contains five elements: (a) alignment with curriculum standards and benchmarks; (b) pre and post activity connections are established; (c) experiences are interdisciplinary; (d) a connection is designed between the two experiences; and (e) students produce work through problem-solving and creativity.

Crane, Nicholson, Chen, and Bitgood (1994) indicated that learning in the formal setting can be bridged by informal institutions both in the short-term and long-term scenarios. Miller (2001) argued that effective formal education should be required to utilize the free-choice setting and there is a need for both institutions. In his study, the central role of formal education was reaffirmed in the development of adult science understanding and the role of free-choice science is not in competition to but rather a partner with formal education (Miller, 2001).

Summary

A bridge connects two entities together. On one side of a proverbial mathematical educational bridge, there is a mass of educational knowledge, formal education, more commonly known as the school setting. On the other side, there is a body of educational experience, informal education, which includes institutions like libraries, science centers, zoos, and museums.

The NCTM (2000) was the first professional organization to establish principles and standards to insure high quality math instruction, and guide instruction of formal education. The NCTM (2000) developed principles to build the best practices of mathematics instruction upon, and they include equity, curriculum, teaching, learning, assessment, and technology. Best practices support and challenge students as teachers follow the implementation of standards (The Education Alliance, 2006). However, current practice of the learning of mathematics focuses on memorization more than understanding (Kilpatrick et al., 2008).

The RAND Mathematics Study Panel (2003) report concluded that many teachers in the United States lack knowledge and the proficiency required to teach mathematics. There is much evidence that associated the lack of teachers' effectiveness with a lack of mathematical proficiency, which has had a negative effect on student achievement in mathematics (Gersten et al., 2008; Hill et al.,2008; Kilpatrick et al., 2008; Marzano, 2007; National Commission on Mathematics and Science Teaching for the 21st Century, 2000; National Mathematics Advisory Panel, 2008; RAND Mathematics Study Panel, 2003).

Negative attitudes and math anxiety are a societal issue (National Academy of Science, 2007; National Research Council, 1989). Studies over the last 40 years reported that some elementary educators suffer from anxiety (Ashcraft, 2002; Austin et al., 2001; Beilocket al., 2010; Geist, 2010; Hill et al., 2008; Malinksky et al., 2006; National Research Council, 1989; Stodolsky, 1985; Trujillo & Hadfield, 1999). Wahl (2005) stated that up to 75% of high school graduates have some level of math anxiety. Anxiety in teachers is normally associated with low proficiency and conceptual understanding levels (Hill et al., 2008). Research concluded that this negatively affects student achievement, and in some cases, causes math anxiety and negative attitudes towards mathematics in students (Ashcraft & Kirk, 2001; Geist, 2010; Miller & Mitchell, 1994; Tocci & Englehard, 1991).

Neuroscience concluded that although no two brains learn alike, the process of learning remains the same for all brains (Jensen, 2005; Sousa, 2008; Tokuhama-Espinosa, 2011; Willis, 2010). Brain research concluded that emotion plays an important part in learning, and learning requires a positive environment without negative emotion (Jensen, 2005; Sousa, 2008; Tokuhama-Espinosa, 2011; Willis, 2010).

The Experiential Learning Theory as well as Social and Cognitive Constructivism Theories support learning in both the formal and informal educational settings (Hein, 1991; Hein & Alexander, 1998; Kolb, 1984; Kolb et al., 2000; Ojose, 2008; Powell & Kalina, 2009). Informal education with its hands-on experiential nature supports science (mathematics) instruction (Lebeau et al., 2001; Miles, 2002), and the objective of museum design is to evoke emotion and through the emotion bring about the learning (Caban et al., 2000).

Good exhibit design engages all the senses of a visitor and drives the visitor to investigate (Falk & Dierking, 2000; McClean, 1993). Exhibits require a quality idea as well as quality design (Falk & Dierking, 2000). Caban et al. (2000) studied exhibit designers and concluded the three most important skills or attributes in design practice are communication skills, technical skills, and creative thinking. Text and writing on exhibit labels needs careful planning as the message needs to reach all visitors and visitors' do not attend to long-worded labels (Carliner, 2003; Falk & Dierking, 2000), and good exhibit design allows for the physical needs of the visitor (Carliner, 2003; Falk & Dierking, 2000; McClean, 1993). Finally, Miles (2002) suggested that "overarching principles" of museum design that focus the designer on the learner's needs which are knowing what is going on, knowing what to do, wanting to do it, and wanting to try to attempt the activity.

The informal free-choice community is working to be a part of the educational system as the informal setting lends itself to the goal of formal education to move away from rote learning to the understanding of concepts (Frankel, 2001; Lebeau et al., 2001). Informal educational facilities create a bridge to assist with the deficiencies in the formal education setting (Crane et al., 1994). The next chapter describes the Math Center as an informal educational facility and the ways it bridges and supports the goals of the formal setting.

Chapter Three: Conjoining the Two Learning and Informational Masses: The Math Center - The Bridge Deck

Founded in 2006, the Math Center piloted its first exhibits during the 2006-2007 school year, and opened in a 3,000 square-foot facility on September 8, 2007. The researcher, serving as a fifth grade teacher, synthesized her observations of teachers and students, when engaged with instructing and learning mathematics, to create exhibits, which would demonstrate to children how math works in order to positively affect attitudes toward mathematics. She engaged in a brainstorming session with a trusted colleague, which resulted in the idea of bringing authentic mathematics instruction into the schools and the lives of students thus potentially affecting a positive change in attitudes towards math.

Paving the Way to the Math Center

The plans for the Math Center did not originate from a collection of data from researched studies in the formal or informal education fields. However, the data from research studies does support the need for a program that is contained in the Math Center. The researcher filed for incorporation and secured approval for nonprofit status from the Internal Revenue Service (IRS). Members of a graduate class at a local university, which contained elementary, middle school, and high school teachers, were surveyed and data were collected to build support for a mathematics center. Question two on the survey, “The opportunity to take my students to a mathematical facility that my students can tour and that makes activities specialized to my needs and the needs of my students would be useful to me” provided supportive data (see Appendix B). Seventy-six percent of high school teachers from 13 schools in 12 school districts agreed or strongly agreed; 57% of middle school teachers from 13 schools and nine school districts agreed or strongly agreed; and 95% of elementary teachers from 27 in 16 school districts agreed or strongly agreed. The conclusion drawn from the survey was that there was a great need for a hands-on mathematical facility.

During the summer of 2006, the idea moved into reality when a local school district agreed to pilot the exhibits as part of an after-school extension program during the 2006-2007 school year. The exhibits were designed, funded, and built by the researcher, and with the help of the board, they were temporarily installed in a multipurpose classroom at the school. The researcher was to train the staff on how to use the exhibits at the beginning of the year and throughout the school year each time the exhibits were exchanged to enhance their instructional practices. The exhibits were changed two more times; however, due to scheduling conflicts, professional development occurred only at the beginning of the year. Feedback from the school was positive, but there were no data collected on the success or failure of the pilot program.

Towards the end of the pilot program, during the spring of 2007, the board worked to move the pilot program to a proto-type facility. The researcher approached several local churches about using any extra space available for the proto-type Math Center. A local Baptist church with a great commitment to the community donated and welcomed the Math Center into 3,000 square-feet of space to establish the hands-on prototype lab. The researcher improved the designs from the pilot program, repurposed fixtures from a craft business, and purchased additional supplies to expand into the 3,000 square-foot space by investing her teacher's retirement into the project.

The prototype lab opened on schedule on September 8, 2007 (9-8-7). The countdown to students learning to love math had begun. The Math Center charged admission and was open to the public. Admission to the general public was five dollars per person and was discounted for field trip visitors to three dollars per student. Teachers and parent guides were admitted at no cost in lieu of their assistance to the students. In 2008, the Math Center employed two part-time employees to assist in facilitating the field trip visits.

By far, the greatest percentage of the clients served were students on field trip visits. The Math Center served approximately 1,700 students during the first three months of operation. In subsequent years, the Math Center served approximately 2,000 students in 2008; 4,000 students in 2009; 3,000 students in 2010; and 3,000 students in 2011 until April 22, 2011 when the church suffered damage from a tornado that caused the Math Center to cease all operations at the facility. Some exhibits were destroyed, but most endured the storm and are in storage. The Math Center's delivery model was changed to go into schools, which is how the Math Center is currently operating, as the process of reopening in a new location is currently underway.

The Galleries or Four Rooms. The area provided for use by the Math Center was already divided into four large classrooms. The doorway in each of the four rooms was decorated with colored tape and named for the color of tape in the doorway. The first room was named the Red Room, where Math Town, Measurement Mania, and The Story of Math were located. In NCTM and GLE terms, this area covered Number Operations and Measurement. The next room was the Orange Room, the room where Probable Probability, Awesome Algebra, Gigantic Geometry, and Dazzling Data were located. In NCTM and GLE terms, this area covered Algebraic Thinking, Data and Probability, and Geometric and Spatial Reasoning. The next room was the Yellow Room where The DaVinci Mode, The Young Child Area, and Math and Music were located. This room contained a blend of the NCTM standards and GLEs. The last room, and most often a visitor's favorite, was the Green Room where Get Your Game on was located. The games in this room, many giant-sized, engaged the visitor in game theory, problem solving, and logic.

Exhibit and Activity Design. There were approximately 25-30 exhibits and activities in each room for visitors to explore freely as they chose. The focus of the design of the exhibits was to make math bigger than life by using giant-size manipulatives and exhibits. The purpose for the giant-size manipulatives was to involve the child's whole body and mind into the experience, and thus, cause the child to become a part of mathematics. In a 3,000 square foot space, there was only room to make some of the exhibits giant-size. Some specific giant-size exhibits were a four-foot protractor with two-foot to three-foot shapes to measure, a bowling alley with three-foot tall foam bowling pins and an eighteen inch foam bowling ball, two three-foot square geoboards, a chess board five-foot square with pieces eight to 12 inches tall, two three-foot square checker boards with pieces three inches in diameter, 30-inch square Tangrams, a five-foot square Chinese Checkers game, a three-foot square Sudoku game, and a five-foot square math equation game. Most of the giant-size exhibits were designed and built by the researcher with the help of volunteers; however, a few were purchased. The remainder of the exhibits incorporated the use of other manipulatives that demonstrated mathematical operations, mathematical concepts, and provided opportunities to practice math in fun and meaningful ways.

Instructions for each exhibit or activity were displayed either on the wall or on the floor next to each exhibit to engage visitors' participation. When possible, the instructions were differentiated for the different experience levels of the visitors. The Math Center communicated to guests that math was not about being smart, but rather the experience of the visitor. Some visitors to the Math Center were beginning mathematicians; others were experienced mathematicians who needed to be challenged. A green level was designated for the visitor with no experience; a blue level was for the visitor with some experience; a black level was for the visitor with experience; and the red level for those ready for a mathematical challenge. Color coded levels were indicated on the exhibit instructions. An example of the differentiated levels would be the exhibit, *Stretch Your Knowledge*, a giant-size geoboard. The visitor may engage in the exhibit at different levels: at the green level, the visitor created lines and segments and worked with those geometrical terms; at the blue level, the visitor created polygons and worked with those geometrical terms; at the black level, the visitor added and subtracted fractions; and at the red level, the visitor multiplied and divided fractions.

All exhibits and activities in the Math Center were aligned with the Missouri Grade Level Expectations (GLEs) which were derived from the NCTM standards. The instructions for the exhibits presented problem-solving situations for the visitors to solve and concrete mathematical experiences for the visitors to apply their classroom instruction. There were approximately 120 different exhibits and activities in the Math

Center (see appendix C). The amount and selection of activities provided visitors with abundant opportunities to experience what the Math Center offered.

The Standard Field Trip Experience. The Math Center's field trip experiences evolved from listening to the needs of teachers. In the beginning, the length of the visit was determined by visiting educators and adjusted accordingly. After several months of operation, it was clear that educators preferred a two-hour, 15-minute visit for the most efficient scheduling of time during the school day and for economical transportation costs.

A two-hour and 15-minute visit was structured so that the students entered the Red Room for a 15-minute talk on why the Math Center existed, the plan for the day, the structure and organization of the visit, and where the restrooms were located. The students were then directed to the room in which they would begin. Students were to have been placed in groups of four by the teacher before arriving to the Math Center to facilitate teams working together at the exhibits. The students spent 25 minutes in each room before rotating to the next room. The sequence was not significant to the design so it did not matter where a class started their visit at the Math Center.

In preparation for the visit, teachers and parents received a guide to help them facilitate the visit for the students (see Appendices D and E). Both teachers and parents were encouraged to preview the Math Center to prepare for visits, and if that was not possible, a photo tour of the Math Center was placed on its website for teachers and students to view before their visit. The teacher's guide specifically described the structure of the field trip visit, made suggestions on how to organize the visit for the students, and included ten activities to extend the visit back in the classroom.

A Customizing Menu (see Appendix F) was created so that educators could select specific activities to focus the visit with classroom and/or grade level instruction. Teachers selected the *Question of the Day* in which data was collected from students and sent back to school to be used at the teacher's discretion. A favorite *Question of the Day* selected was, "What is your favorite subject in school?". Teachers selected art activities for students based upon their instructional needs, and teachers were able to select the playing level of certain games.

Upon arrival, the visitors were directed into the Red Room for a pre-visit orientation. The visitors were guided to the room in which they were to start by Math Center personnel. Visitors spent 25 minutes in each room and then were guided by Math Center to rotate to the next room. The level of participation varied as visitors self-selected the exhibits to experience and explore. At the end of the visit, the teachers received the artwork from the students that had been collected by Math Center personnel to return to the teachers to take back to school for the students. They also received the data from the Question of the Day. Before leaving, the Math Center staff always asked each group of students in each room, "Where do you find math?" If needed, the students were reminded that they had worked with math and money, math and measurement, math and games, math and sports, math and art, etc. The design of the Math Center was for all visitors to leave with the new knowledge that math was everywhere and in everything and with the feeling that math was fun.

Summary

The Math Center was born of a desire and passion to assist people of all ages to gain positive attitudes towards mathematics. The design, although not researched previous to construction, is supported by research on learning mathematics in the formal educational setting as well as the informal educational setting. Students from all over the entire metropolitan area visited the Math Center. In the three and one-half years the prototype lab was operational before damage from the tornado ceased daily operations, 14,000 students visited the Math Center along with their teachers and parents.

Chapter Four: The Method to the Madness – The Bridge Inspection

Students are not making adequate achievement gains in mathematics, and as many as 75% of students leave high school with mild to severe math anxieties (Wahl, 2005). There are several causes for math anxiety, and among the reasons are parents with negative attitudes, insensitive teachers, teachers with low mathematical proficiency levels, or teachers with math anxiety (Geist, 2010; Popham, 2008; Scarpello, 2007; Stodolsky, 1985; Tocci & Englehard, 1991). Math anxiety and negative attitudes toward mathematics interfere with learning mathematics (Hardiman, 2010; Hinton et al., 2008; Jensen, 2005; Sousa, 2008; Tokuhama-Espinosa, 2011).

Jensen (2005) and Sousa (2008) agreed that engaging emotion and senses is necessary for learning to occur. Caban et al. (2000) stated that the more the emotions and senses are engaged, the higher the educational value. Therefore, it is imperative to address the negative attitudes and anxiety towards mathematics as they stand in the way for improving mathematical understanding.

This chapter explains the methodology employed in this study to determine and examine the effects of a two-hour visit to the Math Center on lessening negative attitudes and math anxiety of teachers and students. It also contains a description of participants; an explanation of the design of the study; the treatment, purpose, and rationale for the study; research questions; instrumentation; and data analysis procedures.

Research Methodology

The research methodology for this project was based on a mixed-methods approach with a triangulation design. Mixed-methods research incorporates both quantitative and qualitative research methods. Triangulation, or more specifically methodological triangulation, in a mixed-method study describes two different ways "to study the same phenomenon to determine if the two converge upon a single understanding of the research problem being investigated" (Fraenkel & Wallen, 2009, p. 561). The research from this project intended to delineate what benefit(s) a visitor gained from a two-hour-field trip experience at the Math Center, an informal educational facility that employs hands-on interactive mathematical activities and exhibits in a museum setting. The researcher believes the definition of "benefit" must include cognitive, social, and affective factors that either positively or negatively influence the learning of mathematics.

Since emotion drives learning and negative emotion evokes anxiety, instruments to measure attitudes and anxiety towards math were necessary. These data are best described and compared in quantitative terms as the instruments available to measure anxiety levels require the participant to rate his or her personal level of anxiety. Qualitative data were collected using a knowledge concept map from responses to the question, "What is Math?" To determine the outcomes of the overall experience for visitors, interviews and focus groups, qualitative data were necessary, which allowed the participants to share their thoughts and feelings about the pre-trip information and two-hour field trip experience.

Participants

Prior to the start of the study, invitations were sent by email, letters, and personal contact to schools and district math coordinators in a three county area surrounding the Math Center. Emails soliciting participation in the study were distributed to the Math Center's contact list of visitors and supporters. In addition, posters were displayed and brochures were distributed at the Math Center and at the university where the researcher teaches a course titled Elementary Math Methods. The participants were selected and data were collected over a four-month period between February and May 2011. Participants in this study were volunteers who received free admission to the Math Center in exchange for their participation in the study. Both the treatment group and the control group received free admission; however, the control group's visit was delayed until the completion of the study.

Students. School District A is located in the north area metropolitan region, and two elementary schools from the district participated in the study. Two fifth grade classes from School A1 participated in the study. The experimental class, which received the treatment, was composed of 20 students and a female teacher. The control class contained 24 students and a male teacher. The demographics for School A1 are presented in Table 1 and the math MAP scores for the past three years are reported in Table 2. Two third grade classes from School A2 participated in the study. The experimental class, which received the treatment, was composed of 26 students and a female teacher. The control class contained 25 students with a female teacher. The demographics for School A2 are presented in Table 1, and the math MAP scores for the past three years are reported in Table 2. Both School A1 and School A2 were almost 20% below the state average proficiency level. Parental permission was obtained for all students who participated in the study (see Appendices G and H).

Table 1

Study Sample Demographics

	Asian	Black	Hispanic	Indian	White	Free Reduced-Price Lunch
State	1.8	17.1	4.5	0.5	74.7	47.8
District A	0.5	76.5	2.3	0.1	15.9	68.8
School 1	0.0	92.5	0.7	0.0	2.2	87.8
School 2	0.8	47.6	4.0	0.3	41.0	48.4
District B	2.2	38.9	12.7	0.5	44.3	73.2
School 3	1.4	38.9	18.8	0.7	38.5	80.7

Note. The values represent percentage of each category in the total district or school population

Table 2

Missouri Assessment Program Mathematics – Category Score Percentages

	2011			2010			2009		
Grade 5	State	District A School 1		State	District A School 1		State	District A School 1	
Advanced	16.97	10.40		15.74	15.80		12.06	2.10	
Proficient	36.36	16.70		36.62	18.40		35.73	35.40	
Basic	40.64	56.30		41.49	63.20		44.79	50.00	
Below Basic	6.02	16.70		6.15	2.60		7.43	12.50	
Grade 3	State	District A School 2	District B School 3	State	District A School 2	District B School 3	State	District A School 2	District B School 3
Advanced	12.09	11.80	13.60	10.91	6.70	5.10	9.19	5.30	2.80
Proficient	38.06	21.60	24.20	36.88	41.70	25.60	35.08	43.90	29.20
Basic	44.30	66.70	51.50	46.12	46.70	57.70	49.25	43.90	50.00
Below Basic	5.55	0.00	10.60	6.10	5.00	11.50	6.48	7.00	18.10

Note. The values represent percentage of students in each category

School District B is located in the north area metropolitan region; one school, School 3 participated in the study. The first grade classes and one, third grade class participated as experimental groups; neither level had a control group as District B requested that their students receive the treatment at one time. Three female teachers and

52 students from the first grade participated in the study. One female teacher and 16 students from the third grade participated in the study. The demographics for School B3 are listed in Table 1, and the math MAP scores for School B3 are reported in Table 2, and there are no scores reported for the first grade as first grade students are not MAP tested. Parental permission was obtained for all students who participated in the study (see Appendices G and H).

In-service Teachers. Teacher participation varied throughout the three schools that participated in the study. The teachers at School A1 both participated in the study; however, the treatment teacher at School A1 completed the testing instruments for the study while the control teacher did not. This was not discovered until the end of the study. In School District B, there were no control groups, as the district requested all participants receive the treatment at the same time. Permission to participate in the study was obtained from all in-service teacher participants (see Appendices I and J).

Pre-service Teachers. Students from a local university's Elementary Math Methods classes participated in the study. The university is located in the west area metropolitan region. The university offered four sections of Elementary Math Methods classes during the spring of 2011. Three sections were students of the researcher, and one section was students of the other adjunct professor who had instructed the course over the past 10 years. The pre-service teachers received instruction using the same textbook; however, the control group received instruction at the university and a local elementary school, which included practicum teaching experiences. All sections included both graduate students seeking Master Degrees in Education and undergraduate students who were either juniors or seniors.

The treatment group consisted of 42 pre-service teachers instructed by the researcher. The Tuesday AM section was composed of 22 undergraduate students, 18 female and four male, and two female graduate students. The Tuesday PM section consisted of 11 undergraduate students, all female, and four graduate students, one male and three female. The Thursday PM section contained one female undergraduate student and two male graduate students, one who instructed mathematics at a middle school in an area school district. All students signed a consent form to participate in the study (see Appendix K).

A female professor, colleague of the researcher, instructed the nine persons who participated in the study as members of the control group. Eight of the nine students who participated in the study were undergraduates, seven females and one male, and one graduate female student. All students signed a consent form to participate in the study (see Appendix L).

Quasi-Experimental Design

This design was employed since random assignment was not a feasible alternative for this study. The matching-only pre-test-posttest control group design and the one-group pre-test-posttest experimental designs were utilized in this study. To create a control, the time span between the visits of the treatment and control groups, which visited the Math Center, varied. All treatment groups and control groups completed all pre-tests, post-tests, or post-post-tests at the same time; however, the treatment group visited the Math Center six weeks prior to the control group. This design allowed for a comparison of the data between the treatment group that had visited the Math Center and the control group that had not, and delayed their visit to the Math Center until the data were collected and the study was complete. The classes from School District A and the pre-service teachers followed this design. The classes that participated in School District B were not able to visit the Math Center six weeks apart to create a control, which caused a one-group pretest-posttest design. Figure 1 illustrates the time line for the study.

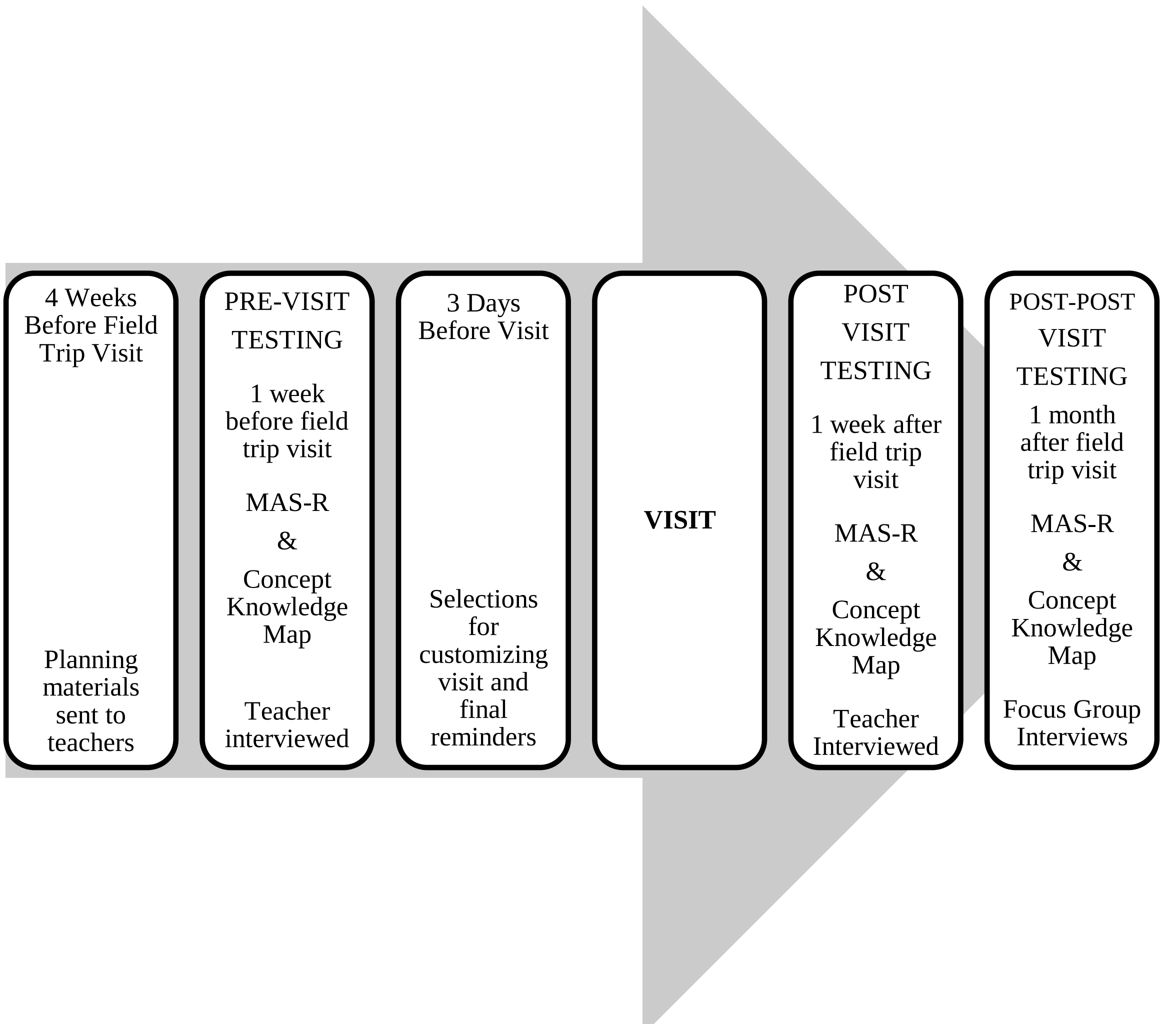


Figure 1. Participant Timeline of Study Events

Matching-Only Pre-test-Post-test Control Group Design. In order to control threats to internal validity, a matching only design was implemented in School District A as students were assigned to classes. This design matched the participants in the treatment group and the control group on certain variables (Fraenkel & Wallen, 2009). Those variables were age and socioeconomic status.

Students. In School District A at School A1 and School A2, the grade level consisted of two classes. One class received the treatment while the other class in the grade level at each school served as the control group. Both groups were administered a Math Anxiety Rating Scale (MAR-S) and a concept knowledge map, one-week pre-visit, one-week post visit, and one-month post-post visit. After the study and collection of the data, the classes that served as the control group received the treatment, which did not affect the results of the data as all data were collected before the visit of the control group. In fact, damage from a tornado prevented either control group from receiving the treatment at the Math Center. The control group received the treatment at their school.

In-service Teachers. In School District A at School A1 and School A2, the grade level consisted of two teachers. One teacher received the treatment while the other teacher in the grade level at each school served as the control. Both teachers were administered a Math Anxiety Rating Scale (MAR-S) and a concept knowledge map, one-week pre-visit, one-week post visit, and one-month post-post visit.

Pre-service Teachers. The involvement of pre-service teachers in the study also followed the matched design. However, the design did not control for demographics as students who attend the university varied. The match existed because all were students in Math Methods classes. The students of the researcher served as the treatment group, and the students of another instructor served as the control. This permitted the comparison of data between pre-service teachers who received the treatment and pre-service teachers who did not receive the treatment as each group was administered the testing instruments concurrently in the same time intervals.

The One-Group Pre-test-Post-test Design. This design was implemented as the volunteers from School District B were not able to visit at two different times six weeks apart as the district requested all participants receive the treatment at the same time. This request was honored to study more participants. This design demonstrated whether a change occurred between pre-visit, post-visit, and post-post visit.

Students. The entire first grade and a third grade class from School B3 in School District B participated in the study following this research design. All student participants from School B3 were administered a Math Anxiety Rating Scale (MAR-S) and a concept knowledge map pre-visit and post-visit.

In-Service Teachers. The first grade teachers and the third grade teacher from School B3 in School District B participated in the study following this research design. Some of these teachers had previously visited the Math Center in prior years. Teacher participants from School District B were administered a Math Anxiety Rating Scale (MAR-S) and a concept knowledge map one-week pre-visit and one-week post visit.

Treatment

The treatment was a two-hour field trip visit to the Math Center; however, the structure of the visit differed for the in-service teachers and their students from the pre-service teacher group. Treatment descriptions follow for each group.

Treatment for In-service Teachers and Student Group. Four weeks prior to the visit, each in-service teacher received the regular planning and organizational information for a visit to the Math Center, revised in January of 2010. This procedural information included a Coordinator Field Trip Planning Guide, Adult Guide Information Sheet, Field Trip Menu Selection, Young Child Guide (only for second grade and younger), and Directions to the Math Center (see Appendices D,E,F,M, and N). Three days prior to each visit, the teacher reported his or her selections to Math Center staff from the Field Trip Selection Menu and the final count for the field trip. Following normal operating procedures, each teacher was reminded: (a) that students should be assigned in groups of no more than four students to work together at the exhibits; (b) of the location of the Math Center; (c) arrival time; and (d) that upon arrival, the buses would be greeted by a Math Center staff member.

Each two-hour visit consisted of four 25-minute sessions in each of the four rooms of the Math Center. Each visit began with a 15-minute introductory informational site speech (see Appendix O), and then students were directed by Math Center staff to the room where they were to begin their first rotation. The teacher, math center staff, and parent guides facilitated the visit and ensured that the students were engaged in the exhibits. At the end of each rotation, students tidied up and then rotated to the next room under the direction of the Math Center staff. This process was repeated until students had visited all four rooms. Before leaving the Math Center, and in accordance with normal operating procedures, each group of students, as they lined up by the door to leave, were verbally asked the question, “Where is math?” In order to elicit a response, math center staff repeated the question adding that the students had worked with math in sports, math in art, math in games, etc. The purpose of this question was to ascertain if the students were able to make the connection to math being everywhere and in everything. All artwork created by the students when the students explored the Yellow Room and data collected from the students' answers to the Data Question of the Day as they rotated into the Red Room were given to the teachers as they left the Math Center to return to school.

Treatment for Pre-service Teacher Group. The pre-service teacher group visited the Math Center as part of their instructional time for an Elementary Math Methods class. The allotted class time was two and a half hours, but students were allowed 45 minutes travel time to and from the university, which reduced the visit time to 1 hour and 45 minutes. The pre-service teacher group visited the Math Center for three classes. The first two visits required the pre-service teachers to use specific exhibits that focused on a particular math concept in the course of study. These exhibits and activities were listed on an instructional sheet and the students received directions on what particular activities/exhibits to explore and where to find them. Pre-service teachers were instructed that the order of completion did not matter. Each pre-service teacher was required to complete a booklet for future reference as teachers in the classroom. These booklets contained math topic information as well as ideas for activities and methods of math instruction. The third visit allowed the pre-service teachers free choice to select the exhibits and activities on their own accord. Pre-service teachers worked in self-selected groups of four students or smaller. The pre-service teachers were to reflect on their experience in a reflection. The researcher facilitated the students' visits and answered questions as needed.

Research Purpose and Research Questions

The primary purpose of this study was to determine changes in math anxiety and attitudes toward mathematics instruction and learning as well as mathematical understanding in teachers, their students, and pre-service teachers following participation in the activities of the Math Center. A secondary purpose of this study was to determine the effectiveness of materials provided to teachers before the field trip visit as well as the giant-size exhibits and manipulatives utilized at the Math Center. The effectiveness was evaluated based on answers to the following research questions:

1. What changes do elementary students experience from a visit to the Metamo4ic Math Center, and do they lead to lowering math anxiety, improving attitudes towards mathematics, and/or an increase in mathematical understanding?
2. What changes do in-service elementary teachers experience from a visit to the Metamo4ic Math Center, and do they lead to lowering math anxiety, improving attitudes towards mathematics, and/or an increase in mathematical understanding?
3. What changes do pre-service elementary teachers experience from a visit to the Metamo4ic Math Center, and do they lead to lowering math anxiety, improving attitudes towards mathematics, and/or an increase in mathematical understanding?

Instrumentation

This study employed the use of a paper quantitative instrument to measure levels of math anxiety and a paper qualitative instrument to compare different responses to the question, “What is math?” During each testing session, the instructional leader for the particular class administered each instrument, and participants were given the time they needed to complete the instruments. None of the instruments had a time requirement for administration.

Quantitative Instrument. The Mathematics Anxiety Scale-Revised (MAS-R) (Bai et al., 2009) is a bidimensional affective scale (see Appendix P). Permission to use the MAS-R in this study was granted from Dr. Bai from the University of Central Florida. The MAS-R is a 14-item paper and pencil questionnaire. The responses on the instrument are on a five-point Likert scale. The negative items on the scale scored as follows: Strongly disagree scored 5 points, disagree scored 4 points, neutral scored 3 points, agree scored 2 points, and strongly agree scored 1 point. The positive items on the scale scored in reverse of the negative items so that high scores indicated high anxiety. In a study to measure the reliability and validity of the instrument, the Cronbach’s alpha coefficient reported the internal consistency of the instrument to be .91. The report on parallel-item consistency had a correlation of .87, and the factor loadings ranged from .67 to .89 for the negative affect and from .67 to .87 for the positive affect factor. The instrument, based on the two-factor measurement model, had excellent construct validity in representing math anxiety on a bidimensional scale (Bai et al., 2009). In conclusion, the MAS-R had a high internal consistency, reliability, parallel-item consistency, and construct validity (Bai et al., 2009).

The MAS-R was adapted for use in the primary grades. The Flesch-Kincaid Reading Ease of the MAS-R is 78.6 and the Flesch-Kincaid Grade Level is 4.0. To accommodate younger learners, the instrument was modified by the researcher to a

Flesch-Kincaid Reading Ease of 92.8 and a Flesch-Kincaid Grade Level of 2.3. In addition, the words strongly disagree, disagree, neutral, agree, and strongly agree were modified to smiling or frowning faces (see Appendix Q).

Qualitative Instrument. A concept knowledge map was created by the researcher to compare and look for patterns from the results to the question, "What is math?" (see Appendix R). The design of this instrument originated from the researcher's observations from the responses to that question during the site speeches from previous field trip experiences. Visitors frequently responded that math was, "adding, subtracting, multiplying, and dividing". The definition of math is rooted in Greek and was defined as "a way of learning". The definition has narrowed to cover only the "abstract numerical sciences". Math is more than the manipulation of numbers. It is the "science of patterns". The current narrow definition and views of mathematics may be another factor in why the subject is disliked by many people. Mathematics is used to describe the world in which we live. Numbers tell only part of the story. Numbers may indicate how big or small something is, but they do not define angles, inches, time, pounds, ounces, shapes, lines, etc.

The design of the concept knowledge map contained two printed ovals in the center of the paper. One oval contained the word "Math" and the other oval was blank to initiate the participant to organize his/her thoughts about math. Asking visitors what they have learned is not effective in informal education as knowledge or the learning may not be needed to be recalled by the visitor until a situation presents itself in the future (Falk & Dierking, 2000). A concept map is a graphical tool, which calls the learner to organize and represent knowledge into concepts or ideas written inside circles, ovals, or boxes, and are connected by drawing a line between the ideas (Novak & Canas, 2008). Novak and Canas (2008) suggested that concept maps are also powerful evaluative tools as they are effective in identifying knowledge, "…a learner possesses before or after instruction" (p. 5).

Pre-Visit and Post-Visit Interviews, Observations, and Focus Group Interviews

The researcher, one week pre-visit and one week post-visit, interviewed the teachers from the treatment group. The pre-visit interview investigated the quality and effectiveness of the pre-trip materials, preparation of the students, and the teacher's reflections on classroom practices (see Appendix S). The post-visit interview investigated changes in student and teacher behavior, the impact of the giant-size exhibits, and the alignment of the exhibits with curriculum (see Appendix S).

An independent evaluator interviewed the pre-service teachers who were students in the researcher's Math Methods class. The pre-visit interview investigated student expectations and attitudes, anxieties, and proficiency levels with mathematics. Inadvertently, the independent evaluator conducted a post-visit interview of the pre-service teachers following the format created for the in-service teacher post-interview. The independent evaluator also conducted a focus group interview one month post visit. The focus group interview investigated the effectiveness of the visit, future usefulness, the importance of the giant-size manipulatives, and improvements needed to the Math Center (see Appendix S).

To guard against researcher bias, an independent evaluator observed all fieldtrip treatments. The independent evaluator observed all parts of each visit beginning with the onsite speech through the departure of the visitors. An observation form was developed from examples of informal observation sheets for the independent evaluator to record his observations (see Appendix T).

The researcher and the independent evaluator conducted a focus group interview with the teachers in the treatment group. The focus group interview investigated the learning opportunities at the Math Center, the effects on instruction, plans for use in the classroom, the giant-size manipulatives, and improvements needed to the Math Center (see Appendix S).

Data Collection Methods

A checklist was provided to the in-service teachers who participated in the study (see Appendix U). The checklist provided ensured consistent data collection at all schools. Instructions for administering the MAS-R and the concept knowledge map were discussed and then sent to each in-service teacher via email in a PowerPoint Presentation (see Appendices V and W). In-service teachers were interviewed at their schools, and pre-service teachers were interviewed at the university. The in-service teacher focus group interview was conducted at the site of the former location of the Math Center.

Data Analysis

The results from each visit were tabulated separately. Each student and in-service teacher participant were assigned an identifying number. As the pre-service teachers were students of the researcher, no identifying numbers were created except for the group of pre-service teachers who volunteered to be part of the interview groups. The responses from each participant on the MAS-R were entered into Excel and tabulated. A positive response to a negatively framed questions scored 5 points on the Likert scale, and a negative response to positively framed questions scored 5 points on the Likert scale. Therefore, the scores reported measured math anxiety. The responses from the concept knowledge map were entered into Excel, coded, and sorted alphabetically. The responses were categorized by the NCTM strands of mathematics: Algebra, Data and Probability, Geometry, Measurement, Number Operations, or Other; or by an Attitude: Positive, Negative, or Neutral. The percentage of responses for each category were calculated. Therefore, the data reflected changes in the thoughts about mathematics and the changes in attitudes towards mathematics.

The MAS-R Inventory

The MAS-R Inventory is a bidimensional instrument. It measures both negative and positive attitudes and anxiety levels using a Likert Scale. Of the 14 questions, eight questions, numbers 2, 4, 6, 7, 8, 9, 11, and 14, were negatively framed while six questions, numbers 1, 3, 5, 10, 12, and 13 were positively framed. Negatively framed questions scored five points for a Strongly Agree response while positively framed questions scored five points for a Strongly Disagree response to measure negative attitudes towards math and math anxiety. A mean was calculated for each student and in-service teacher participant’s responses and for every time each group in the sample completed the MAS-R.

Statistical analyses were performed using the Analysis of Variance (ANOVA) test when pre-test, post-test, and post-post-test means were compared from the matching-only design group of student participants, their teacher, and the pre-service participants. To analyze the one-group design student participants and their teacher, a t Test for difference in means was used. Further analyses were performed using the z Test for difference in means to compare groups of participants pre-test to post-test in both experimental designs, and then post-test to post-post test in the matching only design. An alpha level of 0.05 was used for all tests, and the statistical analyses were prepared in Excel.

The Concept Knowledge Map

A concept knowledge map was utilized to examine patterns from the results to the question, “What is math?” Falk and Dierking (2008) suggested that to ask a visitor what they have learned was ineffective, as the learning may not be recalled until a situation presents itself at some point in the future. The concept map required the visitor to organize, represent, and connect their ideas about math. The question was designed to allow the participant to elaborate on his or her thoughts, beliefs, and knowledge about the subject of mathematics.

In analyzing the data from the concept knowledge maps, responses were coded into two themes: topics of math and attitudes toward math. Math topic responses were coded according to the NCTM strands of mathematics, Algebra (words or statements about patterns or equations), Data and Probability (words or statements about data and probability), Geometry (words or statements about shapes, lines, angles, etc.), Measurement (words or statements about measuring, time, money, temperature, etc.) Number Operations (words or statements about addition, subtraction, multiplication, division, place value, etc.), and Other (words or statements that did not fit into one of the strands of mathematics). Responses pertaining to attitude were coded with Attitude Neutral (general statements about math, “math is everywhere”), Attitude Negative (hate, hard, least favorite subject, etc.), or Attitude Positive (like, love, easy, favorite subject, etc.).

A percentage of each category was calculated for each group of participants pre-test, post-test, and post-post-test. To determine if the participants' view of math expanded, an increase in topics related to math and a decrease in number operation responses were examined. To determine if the participants' experienced a change in attitude, an increase in words like "fun," "exciting," and "amazing" and a decrease in words like "hate," "boring," and "hard" were examined.

Pre-Visit Interviews. The in-service teachers were asked questions to reveal patterns in the quality of the preparation materials sent from the Math Center to the in-service teacher. These materials provide important information to the educator for the organization, structure, and student connections prior to the visit to the Math Center. In addition, the researcher inquired about the teacher's view of his or her attitudes, anxieties, and proficiency levels toward mathematics. The questions were as follows:

1. How did you use the organizational materials to plan the fieldtrip experience to the Math Center?
2. How did you select the activities to customize the visit to the Math Center for your students?
3. How have you prepared your students for the visit to the Math Center?
4. What comments or thoughts have your students expressed about the visit to the Math Center?
5. How can you describe your:
    a. attitude(s) towards learning and teaching of mathematics?
    b. anxieties towards learning and teaching of mathematics?
    c. proficiency with mathematics?

6. How do you characterize the state of mathematics instruction in your classroom?

An independent evaluator interviewed the pre-service teachers by telephone as they were students in the researcher's Math Methods class. The questions were designed to determine patterns in the expectations of their visit to the Math Center. The questions were also designed for the pre-service teachers to self-report on their attitudes, anxieties, and proficiency levels toward mathematics. The questions were as follows:

1. What expectations do you have from a visit to the Math Center?
2. What do you think actually occurs at the Math Center?
3. How can you describe your:
    a. attitude(s) towards learning and teaching of mathematics?
    b. anxieties towards learning and teaching of mathematics?
    c. proficiency with mathematics?

Post-Visit Interviews. The in-service teacher participants were the only group to be individually interviewed after the visit. However, the independent evaluator inadvertently interviewed the pre-service teachers. Both groups were asked questions to investigate the quality of the field trip visit, the ways the teacher had used the visit in math instruction or the ways the pre-service teacher could use the visit in future instruction. Only the in-service teacher group was asked how well the exhibits and activities aligned with curriculum and instruction. The questions were as follows:

1. What comments or thoughts have your students expressed since the visit to the Math Center?
2. How have you utilized the fieldtrip visit in mathematical instruction?

3. What exhibits specifically met the objectives of math instruction in your classroom?
    a. Did the exhibits align with the curriculum in your school and/or district?
4. What impact did the giant-size exhibits have on your students?
5. What impact did the parent guides have on the visit for your students?
6. What changes in attitude, anxiety, and/or proficiency levels with mathematics have you or your students experienced since the visit to the Math Center?
7. What changes have occurred in math instruction in your classroom since the visit to the Math Center?

Focus Group Interviews. Six pre-service teacher participants were interviewed in a focus group setting at the university by the independent evaluator. The questions were designed to ascertain the impact of the visit upon the pre-service teacher and the pre-service teacher's ideas for improvements. The questions were as follows:

1. How does the Math Center provide learning opportunities for both students and teachers?
2. How did the experience at the Math Center affect your understanding of math instruction?
3. How do you plan to use this experience in your future classroom?
4. What is the importance of the giant-size exhibits?
5. How can the Math Center provide access, motivation, and inspiration for students to feel successful at mathematics?

6. How can the Math Center be improved?

Two in-service teachers were interviewed by the researcher and the independent evaluator in a focus group setting after the Math Center was destroyed by a tornado. The questions were designed to investigate the educational value of the visit and gain the in-service teachers' insight into making improvements to the Math Center.

1. How does the Math Center provide learning opportunities for both students and teachers?
2. How did the visit to the Math Center affect your instruction of mathematics?
3. How do you plan to use this experience in your classroom?
4. What is the importance of the giant size exhibits?
5. How can the Math Center provide access, motivation, and inspiration for students to feel successful at mathematics?
6. How can the Math Center be improved?

Observations. An independent evaluator observed each field trip experience. The independent evaluator randomly observed participants and noted whether or not the participants read the directions at the exhibit and whether or not the participants attempted the activity. The independent evaluator observed whether the participants followed the directions as they were written and made note of the participants' level of engagement at the activity. The independent evaluator also recorded the participants' level of frustration and whether the participants completed the activity.

Comparing the Data. The responses from the concept knowledge map were organized and compared in order to ascertain patterns or themes that demonstrated the changes in mathematical understanding and attitudes, thus the effectiveness of the Math Center. The responses from this data were then compared to the responses from the MAS-R by examining the data for a reduction in negative attitudes and math anxiety on the MAS-R and an increase in words and phrases used on the concept knowledge map that indicated an increase in positive attitudes.

The interviews were recorded and transcribed by the researcher. Interviews conducted by the independent evaluator of the pre-service teachers, who were members in the researcher's class, were recorded and then transcribed after the end of the semester when the grades for the course had been posted for the pre-service teachers. Transcriptions were examined for patterns and themes on the effectiveness of the Math Center. These data were then compared to the MAS-R and concept knowledge maps again examining the data to determine a lessening in negative attitudes and math anxiety on the MAS-R, an increase in positive words and phrases used on the concept knowledge maps, and the themes and patterns from the interviews that indicated evidence of the overall effectiveness of the Math Center.

Ethical Considerations

All individuals in this study, in-service teachers, students, and pre-service teachers were asked to participate, and their participation was voluntary. In-service teachers, students, and pre-service teachers were permitted to discontinue their participation in the study at any time. An independent evaluator was employed to protect against researcher bias. All participants received free admission to the Math Center. There was no anticipated risk to any participants of this study. Instruments were number-coded to identify student, in-service teacher, and interview pre-service teacher participants to cross check results, and participants were assured anonymity.

Summary

This study was conducted to determine if participants experienced a lessening of anxiety, an improvement in attitude, or improved understanding of mathematics as a result of a two-hour field trip visit to a Math Center. Since the researcher found a plethora of evidence regarding the effects of negative attitudes and math anxiety on the learning of mathematics, the findings from this study will contribute to possible solutions for improving student achievement in mathematics and provide a model for mathematics education in the field of informal education.

This study implemented the use of the MAS-R, an instrument to measure math anxiety, a concept knowledge map, interviews, and observations to determine the effects of a two-hour visit to a Math Center. The MAS-R was developed in research led by Bai et al. (2009). All other instrumentation was developed by the researcher to ascertain the changes in math anxiety, attitudes, and mathematical understanding. The results from the MAS-R were compared to the results and themes from the concept knowledge maps and the interviews.

Chapter Five: Reporting the Data – "The Math"

This research study examined the effects of a 2 hour and 15 minute field trip visit to a Math Center in a metropolitan area of a major Midwestern city on students, in-service teachers, and pre-service teachers. In order to determine if the visitor experienced a lessoning of anxiety, participants completed the MAS-R inventory pre-visit, post-visit, and post-post-visit. In order to examine the change in knowledge and attitude from the visit, participants completed a concept knowledge map pre-visit, post-visit, and post-post-visit. To study the quality of the visit, the in-service teacher and pre-service teacher groups participated in interviews conducted by the researcher and independent evaluator. In addition, the independent evaluator observed each group of participants during the field trip visit. The design of the study addressed the following research questions:

1. What changes do elementary students experience from a visit to the Math Center and do they lead to lowering math anxiety, improving attitudes towards mathematics, and/or an increase in mathematical understanding?
2. What changes do in-service elementary teachers experience from a visit to the Math Center and do they lead to lowering math anxiety, improving attitudes towards mathematics, and/or an increase in mathematical understanding?
3. What changes do pre-service elementary teachers experience from a visit to the Math Center and do they lead to lowering math anxiety, improving attitudes towards mathematics, and/or an increase in mathematical understanding?

Explanation of the Presentation of Data

This study focused on determining the effectiveness of a field trip visit to the Math Center. A fifth grade class from School A1, a third grade class from School A2, three first grade classes and a third grade class from School B3, their teachers, and three sections of pre-service teachers from a local university's Math Methods classes visited the Math Center on a field trip experience.

The one group pre-test post-test group responded one-week pre-visit and one-week post visit, and the matching-only pretest-posttest control group responded pre-visit, post-visit, and one-month post-post visit to the MAS-R to determine if a lessening in math anxiety occurred. These groups also responded to the question, "What is Math", on a concept knowledge map to determine if their views of mathematics changed. This was demonstrated by a decrease in the percentage of "Number Operation" responses and an increase in the number in one or all of the NCTM strands of math, "Algebra", "Data and Probability", "Geometry", and "Measurement" responses. The concept knowledge map also determined if participants' attitudes improved by showing an increase in the percentage of "Attitude Positive" responses and a decrease in the percentage of "Attitude Negative" responses.

The teachers from Schools A1, A2, and B3 and six pre-service teachers were interviewed one-week pre-visit to determine their expectations, preparation, and self-reported math anxiety and proficiency levels. The teachers from Schools A1, A2, and B3 were interviewed one-week post-visit to determine if the visit met their expectations. The teachers from Schools A1, A2, and B3 participated in a focus group interview one-month post-visit, and six pre-service teachers participated in a focus group interview one-month post-visit. The focus group interviews further examined the expectations and experiences from the field trip visits. The in-service teachers were interviewed by the researcher, and the pre-service teachers were interviewed by an independent evaluator as they were students of the researcher.

Organization of the Presentation of Data. Data in this chapter were organized and presented by each participant group. This permitted a detailed examination of each participant group and a holistic investigation of the field trip experience at the Math Center. First, data from the students and the in-service teacher from the treatment group and the control group from School A1 were presented. Second, the students and the in-service teacher from the treatment group and the control group from School A2. Third, the students and the in-service teacher from each class in District B: First Grade Class A, First Grade Class B, First Grade Class C, and Third Grade from School B3 were reported. Fourth, the data from School A1 and School A2 were presented as a collective total for District A. Fifth, the data from all four classes from School B3 were presented as a collective total for District B. Sixth, the data were compiled for all elementary student participants in District A and District B and presented as an aggregate total for all student participants in the treatment group and then for all student participants in the control group. Seventh, the pre-service teacher participants from the treatment group and the control group were reported. Eighth, the in-service teacher participants from the treatment group and the one representing the control group were stated. Finally, aggregate totals from the MAS-R and the concept knowledge map for all treatment participants from all groups were presented.

MAS-R Reported Data. The MAS-R inventory was used in this study to learn and examine the anxiety levels of the participants before the field trip visit and how their anxiety levels changed one-week after the field trip visit, and in District A, again one month after the field trip visit to the Math Center. A class mean anxiety level and a class median anxiety level from each elementary school, their teachers, and the pre-service teachers were presented in a table format and included the results of the treatment group and the control group. Very high reported anxiety levels and very low reported anxiety levels, outliers, could have affected the mean. Therefore, to determine a lessening of anxiety levels, it was necessary to compare the mean to the median as medians are less affected by outliers and indicated where the anxiety levels fell into the distribution of data either above or below the median. A lessoning of anxiety levels was anticipated for the treatment groups, and the control groups were not expected to change, as they had not received the treatment prior to the testing sessions. A lessening of anxiety was indicated when the mean and median decreased pre-visit to post-visit. As the treatment occurred one month prior to the last testing session, the change in the lessening of anxiety levels from post-visit to post-post visit was not anticipated. Therefore, anxiety levels that remained the same between the post and post-post visit were expected. This expectation was based on research from Farmer et al. (2007) and Falk and Dierking (2000), which stated that learning in the informal educational setting was retained for one year and is recalled as needed by the learning situation.

In addition to the comparison of the decrease in the mean and the median for each class or participant group, a histogram, a visual graphic representation of the distribution of each participant's anxiety level in the class, for each visit follow the reported mean and medians. The histograms provided evidence about how the anxiety level means decreased from pre-visit to post-visit to post-post-visit. A lessening in anxiety was further demonstrated when the histogram illustrated a positive or right-skewed distribution. The histograms for each treatment group were presented, and then were followed by the histograms for the control group. The histograms for the control group were anticipated to remain the same between the testing sessions as the control group had not received the treatment at the time of the testing.

Concept Knowledge Map Reported Data. Based on the researcher's observations during the site speeches in the Math Center prior to this study, a high number of visitors indicated that math was "adding, subtracting, multiplying, or dividing". The concept knowledge map asked each participant to map out and organize his/her thoughts, beliefs, and knowledge of mathematics by asking each participant to respond to the question, "What is math?" Each participant's responses were categorized by the NCTM strands of mathematics, Algebra, Data and Probability, Geometry, Measurement, Number Operations, and Other or by the tone or attitude of the response, Attitude Negative, Attitude Neutral, or Attitude Positive. After each response was coded, a percentage for each category was calculated from every class for each testing session. A vertical bar graph visually displaying the percentages of each category for each elementary class, in-service teacher, and pre-service teacher group pre-visit, post-visit, and post-post-visit follows the MAS-R data reports and illustrates the change in thoughts, beliefs, and knowledge of the class or group of treatment participants and control participants. A table that compiles and numerates the total responses in each category for the student treatment group, pre-service teacher group, and in-service teacher group was provided for reference.

A change in mathematical understanding was demonstrated by a decrease in the percentage of responses in the “Number Operations” category and an increase in any combination of the other NCTM strands of mathematics categories, Algebra, Data and Probability, Geometry, and Measurement pre-visit through the post-post visit testing sessions. A change in attitude was demonstrated by an increase in Attitude Positive responses and a decrease in Attitude Negative responses.

The treatment groups were anticipated to demonstrate a decrease in the percentage of Number Operation responses to establish an improvement of understanding and increase the percentage of Attitude Positive responses to validate an improvement in attitude. The control groups, as they had not experienced the Math Center at the time of the testing, were expected not to demonstrate a change in percentage in any category. As each treatment class and group would most likely have different beginning levels of knowledge and attitudes, the control groups’ responses were not directly compared to the treatment group. The purpose of the control group was to validate the comparison of the changes between the treatment and control groups.

Interviews. The pre-service teacher participants and the in-service teacher participants were the only two groups of participants interviewed for the study. The original design of the study did not include a post-visit interview from the pre-service teacher participants. However, the independent evaluator interviewed the pre-service teachers post-visit following the framework of the questions created for the interviews.

All the pre-visit interviews were reported first, followed by the post-visit interviews, and then the focus group interviews were reported for each participant group.

District A, School 1, Fifth Grade – Matching Only Design

MAS-R Results. Table 3 shows the MAS-R means for all fifth grade participants from School A1. A lessening in anxiety is indicated by a decrease in the MAS-R mean. In order to compare, analyze, and interpret the data from the students in the class to the teacher of the class, the MAS-R data from the students is above the MAS-R data from the teacher of the class. The means for the control group held steady for all three testing sessions. The means for the in-service teacher and students mirror one another. There is a .06 decrease from pre to post visit with the students while the teacher decreases .14. From the post to the post-post testing sessions, the student mean decreases .18 while the teacher mean decreases .29.

Table 3

Summary of Mean Data – School A1

Group	Pre-Visit	Post Visit	Post-Post Visit
Treatment - Students	2.28	2.22	2.04
Treatment - In-service Teacher	2.07	1.93	1.64
Control - Students	2.46	2.51	2.51

Note: Means were calculated for each group that participated in the study. Means were calculated by assigning point values to the responses on the MAS-R. The highest rating score possible was five and the lowest rating score was one.

Table 4 lists the median MAS-R scores for each time the instrument was administered to the participants at School A1. A lessening in anxiety was indicated by a decrease in the mean; however, a decrease in the median MAS-R indicated that overall mean scores decreased. It was important to examine both the mean and the median for each application of the MAS-R to determine if the entire group experienced an overall lessening in an anxiety. The mean is affected by extremely high or extremely low values, outliers, while the median is affected less by outliers and demonstrated how the anxiety levels fell into the upper half or lower half of the values.

Table 4

Summary of Median Data – School A1

Group	Pre-Visit	Post Visit	Post-Post-Visit
Treatment - Students	2.36	2.21	1.89
Control - Students	2.43	2.29	2.29

Note: The median MAS-R scores were calculated for each group that participated in the study. The medians were calculated from the means of each student's anxiety rating on the MAS-R in the class. The highest rating score on the MAS-R possible was five and the lowest rating score was one.

The following histograms in Figure 2, Figure 3, and Figure 4 indicate the frequency and distribution of the MAS-R scores of the treatment group. The frequency of scores demonstrated how the mean scores lessened. Figure 5, Figure 6, and Figure 7 indicate the frequency and distribution of the MAS-R scores of the control group, and demonstrate the consistency of the mean scores in the control group. The treatment group trend in these histograms demonstrated a right skewed distribution of the data, which means the MAS-R levels moved toward the lower values of the frequency distribution while the trend in the control class demonstrated the opposite trend. The control class's MAS-R levels moved toward the higher values of anxiety levels from pre-visit testing sessions to post and post-post-testing sessions.

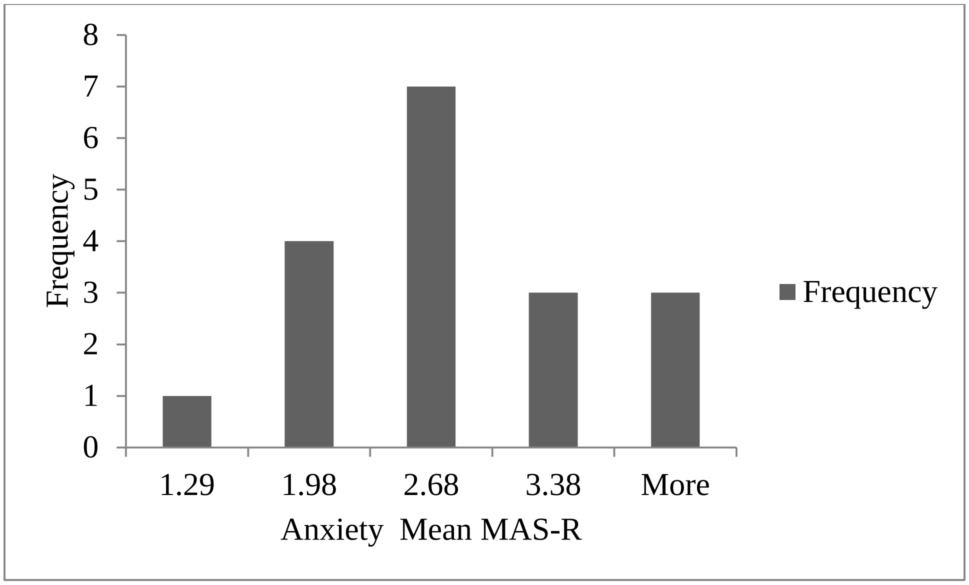


Figure 2. Pre-Visit Histogram Treatment Group School A1

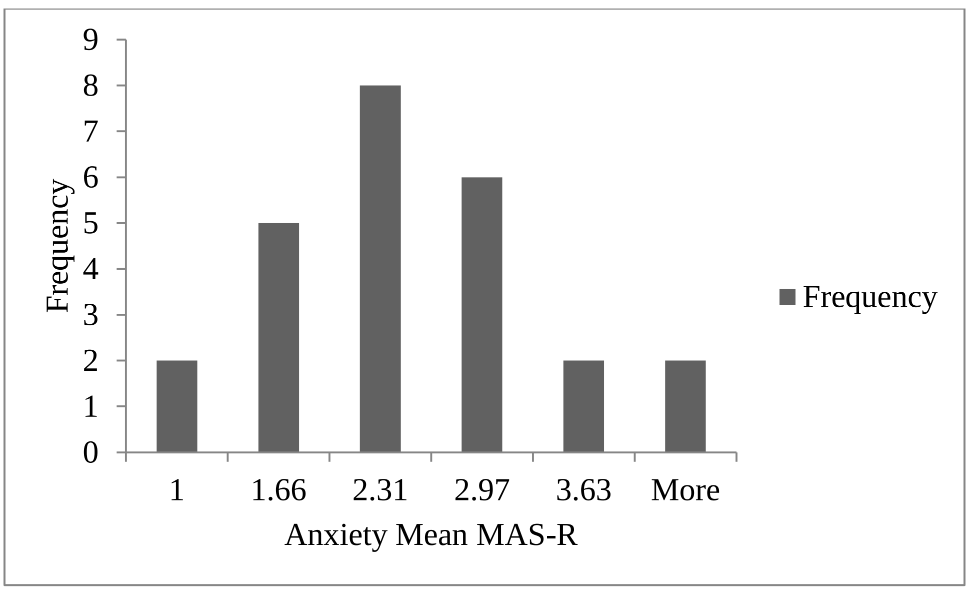


Figure 3. Post-Visit Histogram Treatment Group School A1

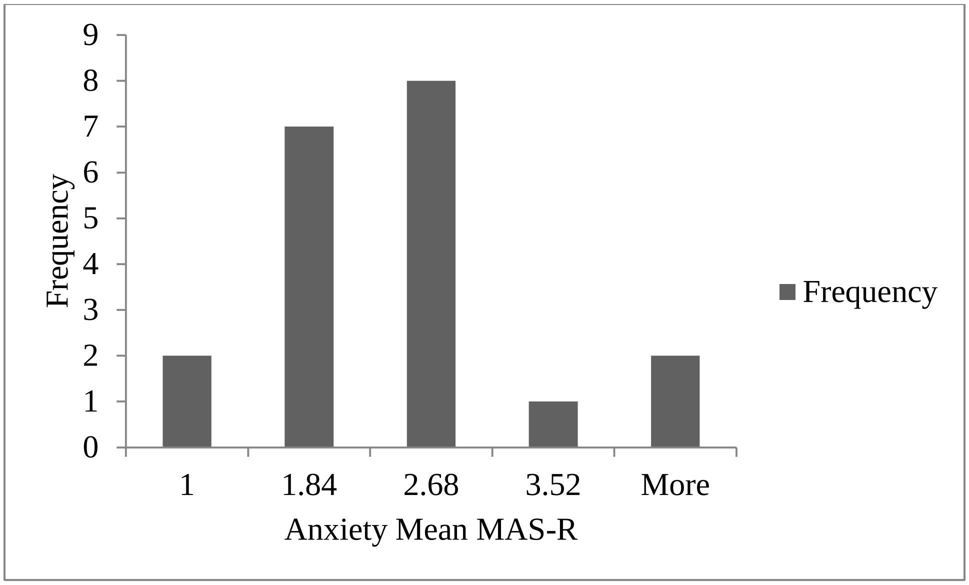


Figure 4. Post-Post-Visit Histogram Treatment Group School A1

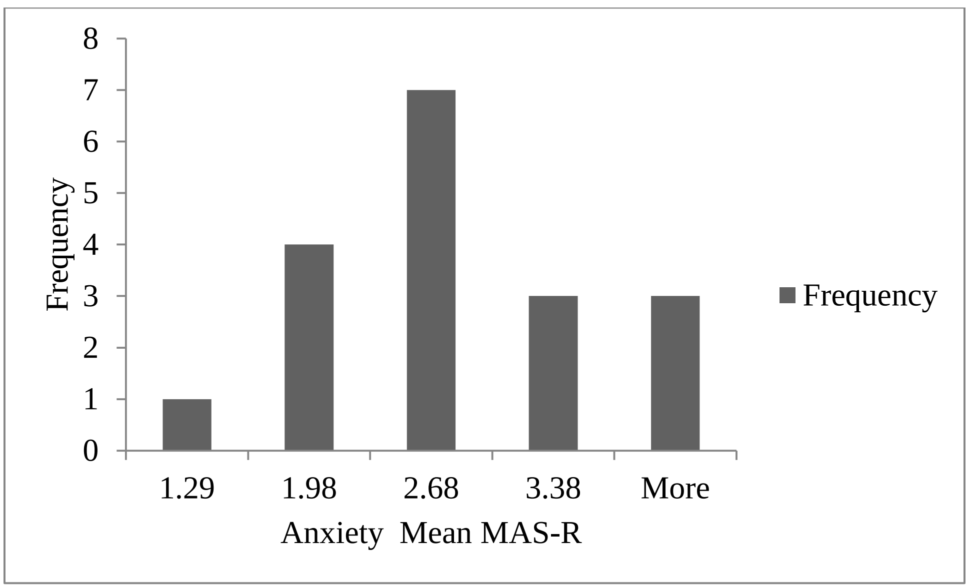


Figure 5. Pre-Visit Histogram Control Group School A1

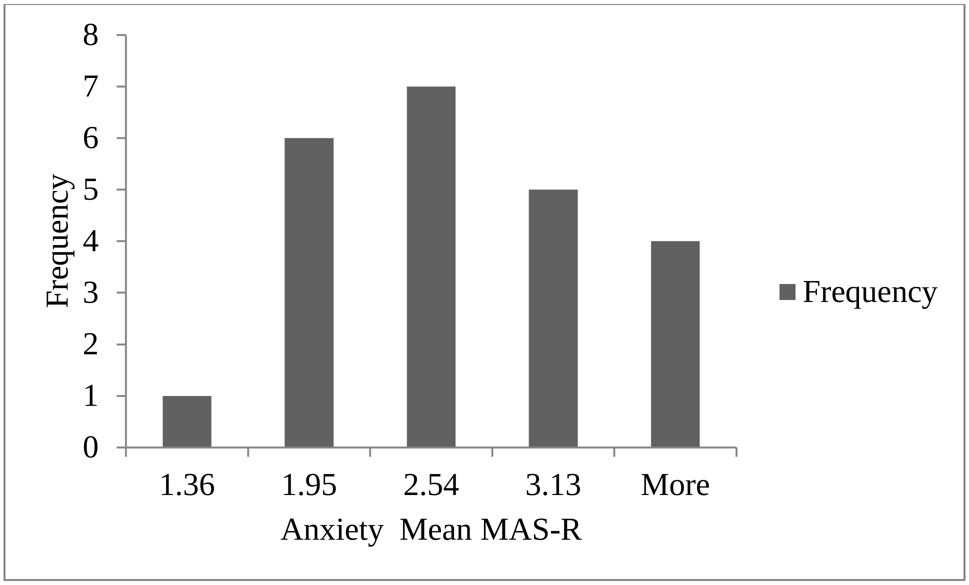


Figure 6. Post-Visit Histogram Control Group School A1

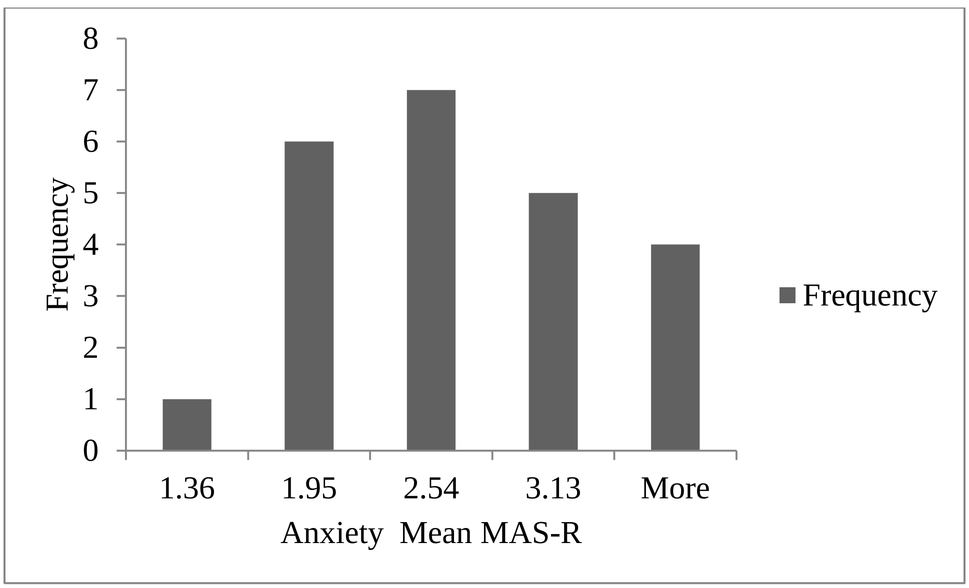


Figure 7. Post-Post-Visit Histogram Control Group School A1

To test for measureable change between repeated applications of the MAS-R, the ANOVA test was performed. The null hypothesis states there will be no difference in mean scores when comparing pre-test, post-test, and post-post-test for the treatment group of students. The p-value from the ANOVA test is .62 for the treatment group. With an alpha level of .05, the decision was not to reject the null hypothesis. The p-value from the ANOVA test is .98 for the control group. With an alpha level of .05, the decision was not to reject the null hypotheses. The p-value indicates the likelihood or probability of obtaining these same test values if the null hypothesis is true. Table 5 shows the ANOVA results for the treatment group, and Table 6 shows the results for the control group of students.

Table 5

ANOVA: Single Factor Treatment Group School A1

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	21	47.857143	2.2789116	0.5280126
Column 2	25	55.428571	2.2171429	0.6889796
Column 3	20	40.785714	2.0392857	0.7945623

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	0.6353982	2	0.3176991	0.4743751	0.6244784	3.1428085
Within Groups	42.192447	63	0.6697214			
Total	42.827845	65				

Note: A p-value of 0.62 > α (0.05) indicates the decision to not reject the null hypothesis.

Table 6

ANOVA: Single Factor Control Group School A1

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	20	49.228571	2.4614286	0.4885306
Column 2	24	60	2.5	0.6626442
Column 3	24	60	2.5	0.6626442

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	0.0210036	2	0.0105018	0.0171668	0.9829841	3.1381419
Within Groups	39.763714	65	0.6117495			
Total	39.784718	67				

Note: A p-value of 0.98 > α (0.05) indicates the decision to not reject the null hypothesis.

To test for measureable change between repeated applications of the MAS-R, pre-visit to post-visit, the t Test for difference in means was performed. The null hypothesis states the post-test results on the MAS-R will not be less than pre-test results for the treatment group of students. The p-value from the t Test is .40. With an alpha level of .05, the decision was not to reject the null hypothesis. The p-value indicates the likelihood or probability of obtaining these same test values if the null hypothesis is true. Table 7 shows the t Test results.

Table 7

t Test School A1 Treatment Group Pre-Visit to Post-Visit

	Variable 1	*Variable 2*
Mean	2.278911565	2.217142857
Variance	0.528012634	0.688979592
Observations	21	25
Pooled Variance	0.615812793	
Hypothesized Mean Difference	0	
df	44	
t Stat	0.265916261	
P(T<=t) one-tail	0.395772897	
t Critical one-tail	1.680229977	

Note: A p-value of 0.39 > α (0.05) indicates the decision to not reject the null hypothesis.

To test for measureable change between repeated applications of the MAS-R, post-visit to post-post visit the t Test for difference in means was performed. The null hypothesis states the post-post test results on the MAS-R will not be less than post-test results for the treatment group of students. The p-value from the t Test is .24. With an alpha level of .05, the decision was not to reject the null hypothesis. Table 8 shows the t Test results.

Table 8

t Test School A1 Treatment Group Post-Visit to Post-Post-Visit

	Variable 1	*Variable 2*
Mean	2.217142857	2.039285714
Variance	0.688979592	0.794562299
Observations	25	20
Pooled Variance	0.735632416	
Hypothesized Mean Difference	0	
df	43	
t Stat	0.691225303	
P(T<=t) one-tail	0.246569528	
t Critical one-tail	1.681070704	

Note: A p-value of 0.24 > α (0.05) indicates the decision to not reject the null hypothesis.

Concept Knowledge Map Results. Figure 8 and Figure 9 summarize the qualitative data for each administration of the knowledge concept map pre-visit, post visit, and post-pos- visit for the treatment and control groups from School A1. A decrease in Attitude Negative responses was observed in the treatment group. Pre-visit responses were 5.3%, post-visit 0.6%, and post-post-visit responses were 1.3%. An increase in Attitude Positive was observed. Pre-visit student responses were 11.6%, post-visit responses 9.2%, and post-post-visit responses were 13.0%. The percentage of Number Operation responses in the treatment group were 52.4% pre-visit, 56.3% post-visit, and 59.1% post-post-visit. The percentage of responses in Algebra, Data and Probability, Geometry, and Measurement held steady or increased from pre-visit to post-visit. All topics but Data and Probability decreased from post-visit to post-post-visit, which increased from 1.2% to 3.9%.

The control group Number Operation responses decreased from 57.1% pre-visit to 43.2% post-visit and remained unchanged at the post-post-visit administration. The percentage of Attitude Negative responses went from 2.7% pre-visit to 7.2% post-visit and remained unchanged at the post-post-session. Attitude Positive responses increased from 4.0% pre-visit to 10.4% post-visit.

These results indicated that the students in the treatment group understanding of mathematics as a diverse body of topics did not change from the visit to the Math Center. The students continued to perceive math as adding, subtracting, multiplying, and dividing. The results indicated that the treatment group of students' attitude shifted slightly to a more positive view of mathematics. The students in the control group results were not anticipated as it was expected that the results of the control group would not fluctuate. The students in the control group experienced an increase in Attitude Positive and an increase in Attitude Negative responses. It is possible that the topic of math instruction in the classroom and MAP testing had an influence on the students.

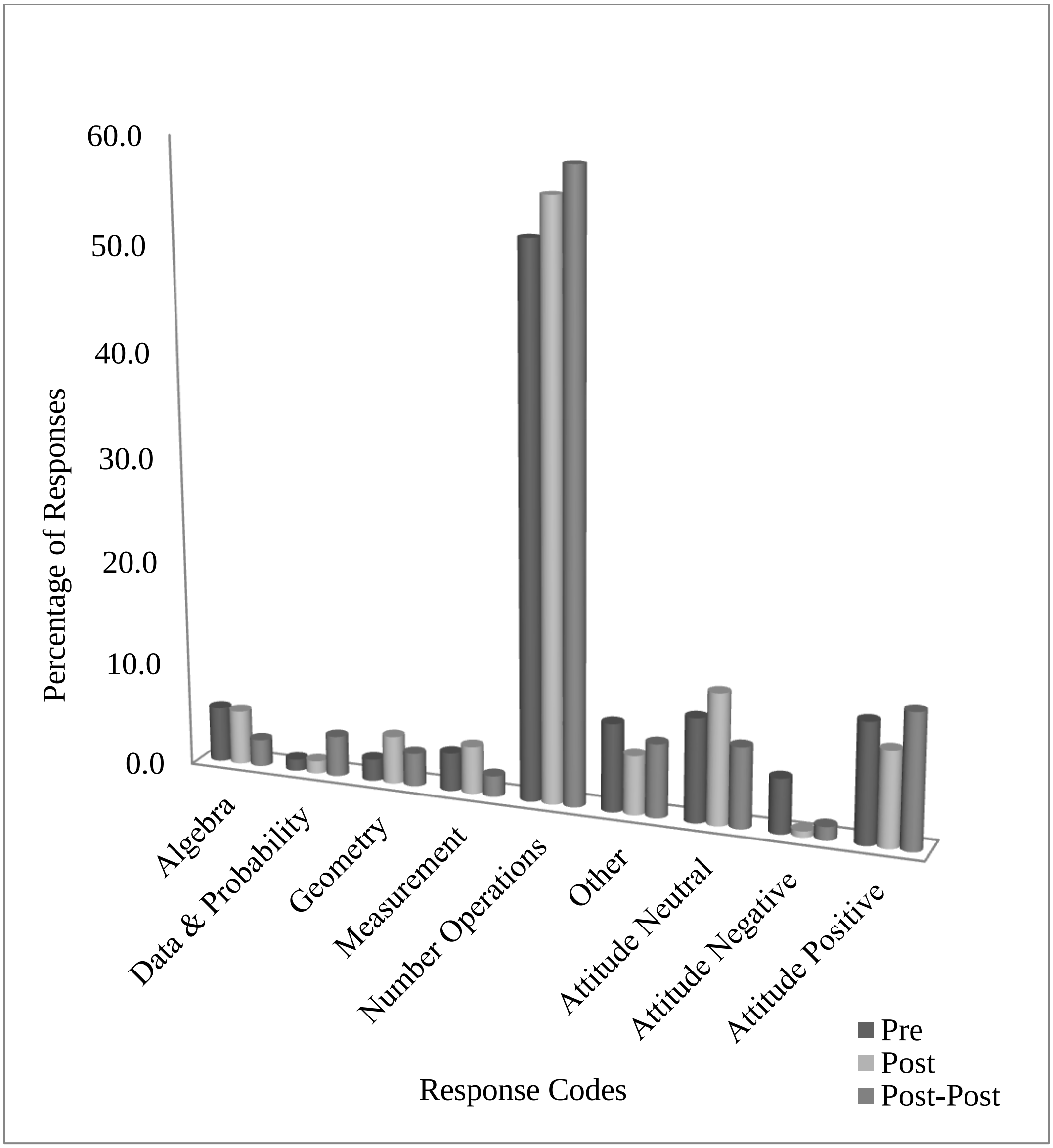


Figure 8. *Student Responses Concept Knowledge Map School A1 Treatment Group – All Testing Sessions*

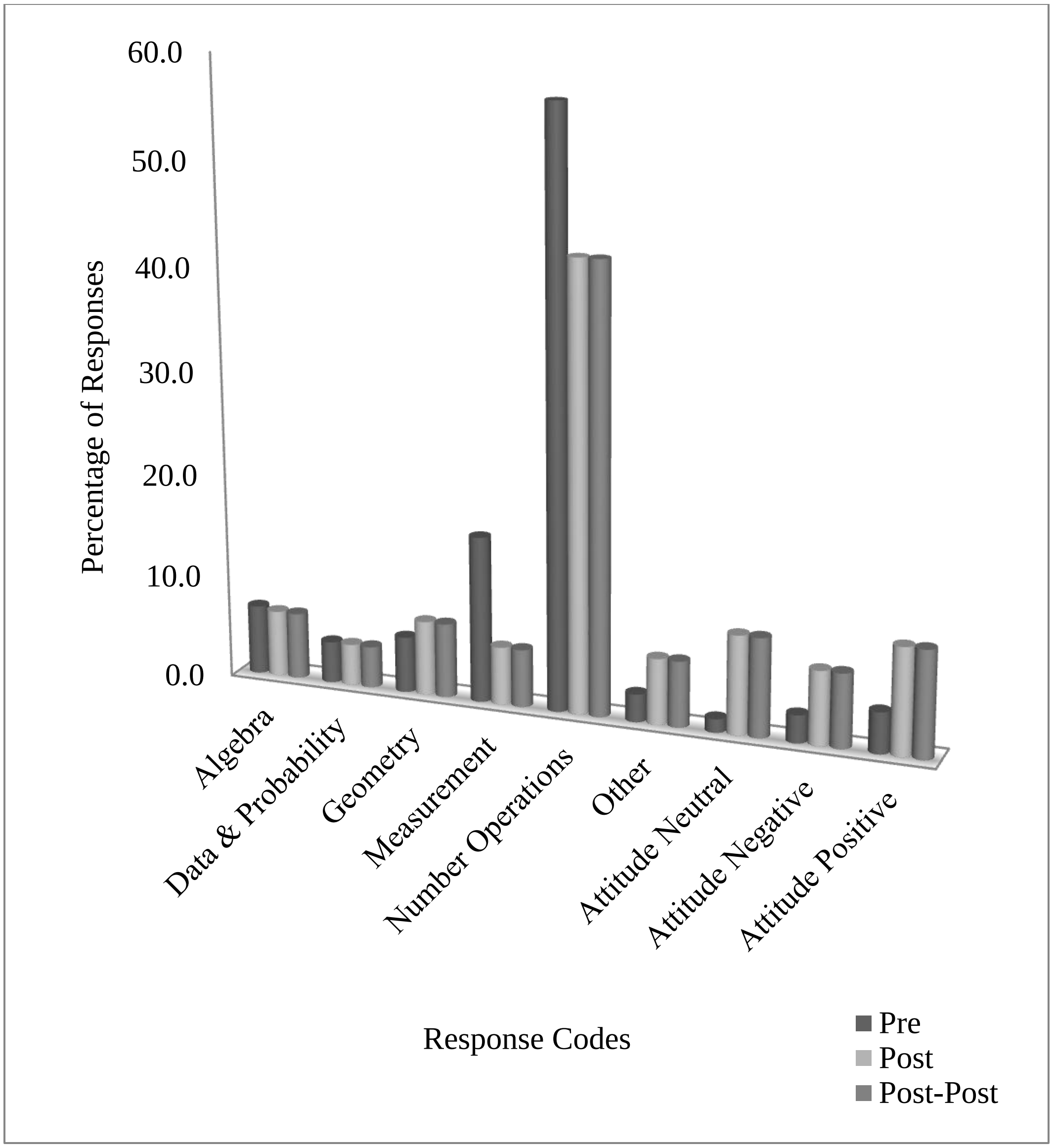


Figure 9. Student Responses Concept Knowledge Map School A1 Control Group – All Testing Sessions

Observations of Independent Evaluator. The independent evaluator made 12 observations of participants during the visit of the fifth grade class from School A1. The evaluator noted that at four of the 12 observations, the participants read the directions and at all 12 observations they attempted the activity. He noted that at all 12 observations the participants were engaged in the activity; however, six of the participants did not follow the directions and interacted with the exhibit with their own rules and ideas of participation. Two students were observed at Measure Island, a measuring island filled with plastic pebble sand. The students used the measuring tools and measured, but not as directed by the posted instructions next to the exhibit. The evaluator reported that during one of the 12 observations, the participant experienced some frustration while the participants observed in the other 11 observations did not experience frustration. The evaluator noted that two of the 12 observations ended with the participants not completing the activity and moving on to another exhibit, and the other 10 either finished the activity or worked at the activity until the end of the time in the room.

District A, School 2, Third Grade – Matching Only Design

MAS-R Results. Table 9 shows the MAS-R means for the third grade participants from School A2. The mean score for the treatment group pre-visit was higher than the post-visit and demonstrated a decrease in anxiety levels from pre to post-visit. The post-post-visit mean score minimally decreased from the post-visit. The mean scores for the control decreased slightly from the pre-visit session to the post-visit. There was no change in the between post-visit and post-post-visits.

Table 10 shows the treatment group demonstrated a decrease in the median level of anxiety scores. Pre-visit the median was higher than the post-visit, and the post-post visit median decreased from the post-visit testing. The control group median scores measured slightly higher than the treatment group at the pre-visit, and the median level of anxiety decreased between the pre-visit and post-visit sessions. The median level of anxiety between post-visit and post-post visits slightly decreased in the control group.

The students in the control results were not anticipated as it was expected that the results of the control group would not fluctuate. It is possible that the topic of math instruction affected these results. These results would indicate that the students' understanding of mathematics as a diverse body of topics did not change from the visit to the Math Center. The students continue to perceive math as adding, subtracting, multiplying, and dividing. The results indicate that the students' attitude shifted slightly to a more positive view of mathematics.

Table 9

Summary of Mean Data – School A2

Group	Pre-Visit	Post Visit	Post-Post Visit
School 2			
Treatment - Students	2.49	2.10	2.09
Treatment - In-Service Teacher	3.71	2.36	1.93
Control - Students	2.39	2.25	2.25
Control - In-Service Teacher	3.29	2.64	2.57

Note: Means were calculated for each group that participated in the study. Means were calculated by assigning point values to the responses on the MAS-R. The highest rating score possible was five and the lowest rating score was one.

Table 10

Summary of Median Data – School A2

Group	Pre-Visit	Post Visit	Post-Post Visit
Treatment - Students	2.39	2.21	2.00
Control - Students	2.50	2.36	2.29

Note: The median MAS-R scores were calculated for each group that participated in the study. The medians were calculated from the means of each student's anxiety rating on the MAS-R in the class. The highest rating score on the MAS-R possible was five and the lowest rating score was one.

The histograms in Figure 10, Figure 11, and Figure 12 indicate the frequency and distribution of the MAS-R scores for each participant's anxiety level in the School A2 treatment group. The frequency of scores demonstrate how the mean scores lessened.

Figure 13, Figure 14, and Figure 15 indicate the frequency and distribution of the MAS-R scores of the control group, and demonstrate the consistency of the mean scores in the control group. The histograms provided evidence about how the anxiety level means decreased from pre-visit to post-visit to post-post-visit. A lessening in anxiety was further demonstrated when the histogram illustrated a positive or right skewed distribution.

The treatment group trend in these histograms demonstrated a right skewed distribution of the data, which means the MAS-R levels moved toward the lower values of the frequency distribution while the trend in the control class demonstrated the opposite trend from pre-visit to post-visit testing sessions. The control class's MAS-R levels moved toward the higher values of anxiety levels from pre-visit testing sessions to post-visit testing sessions.

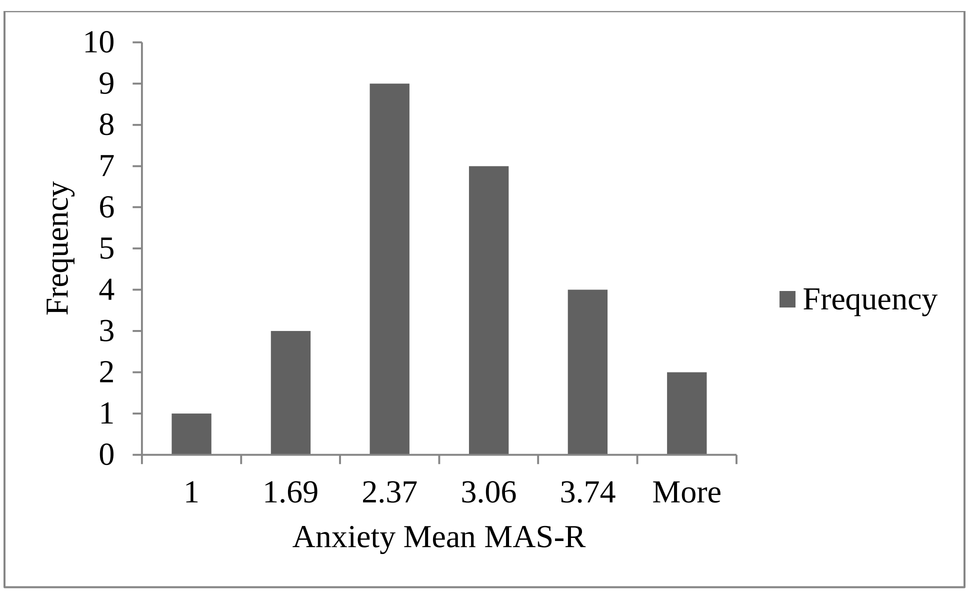


Figure 10. Histogram Pre-Visit Treatment Group School A2

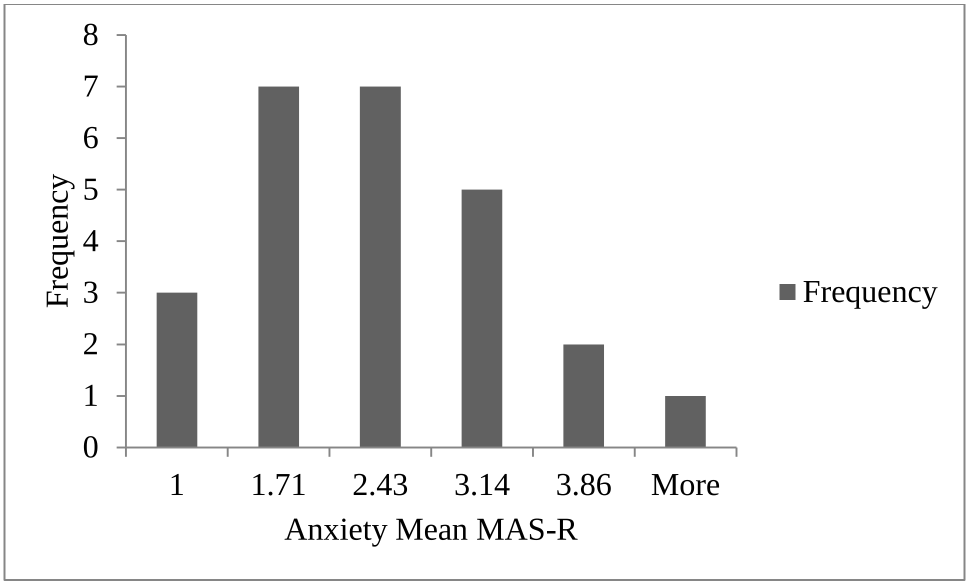


Figure 11. Histogram Post-Visit Treatment Group School A2

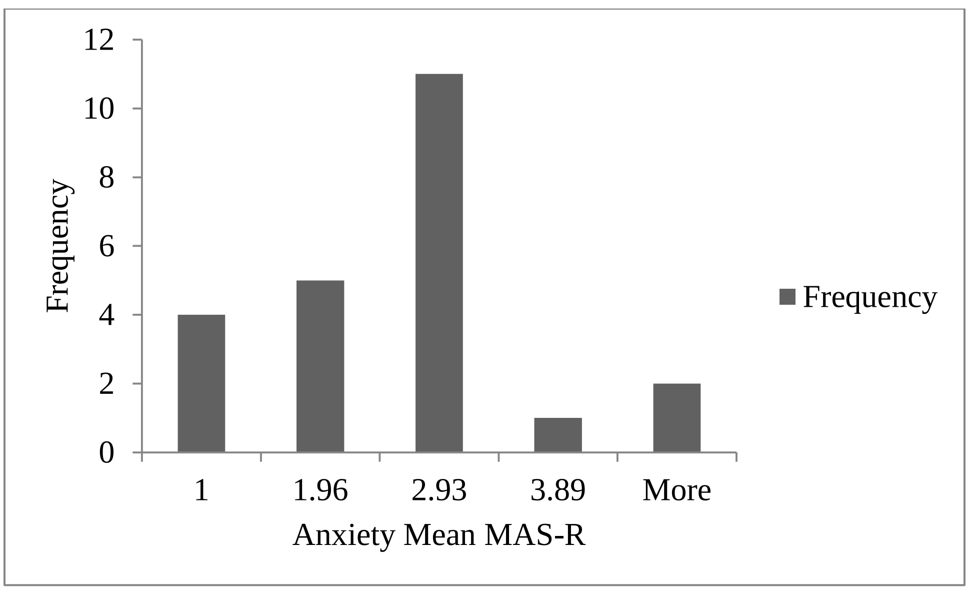


Figure 12. Histogram Post-Post-Visit Treatment Group School A2

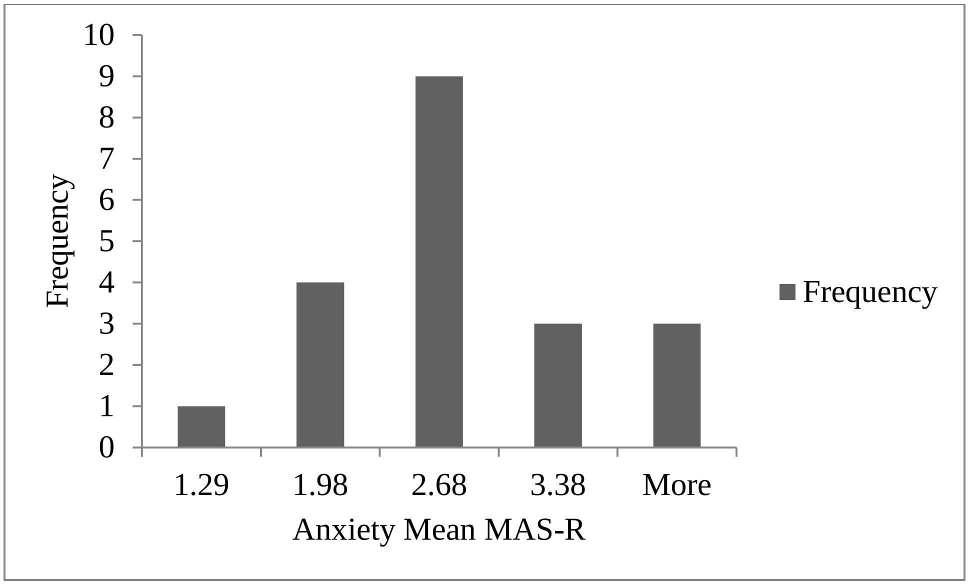


Figure 13. Histogram Pre-Visit Control Group School A2

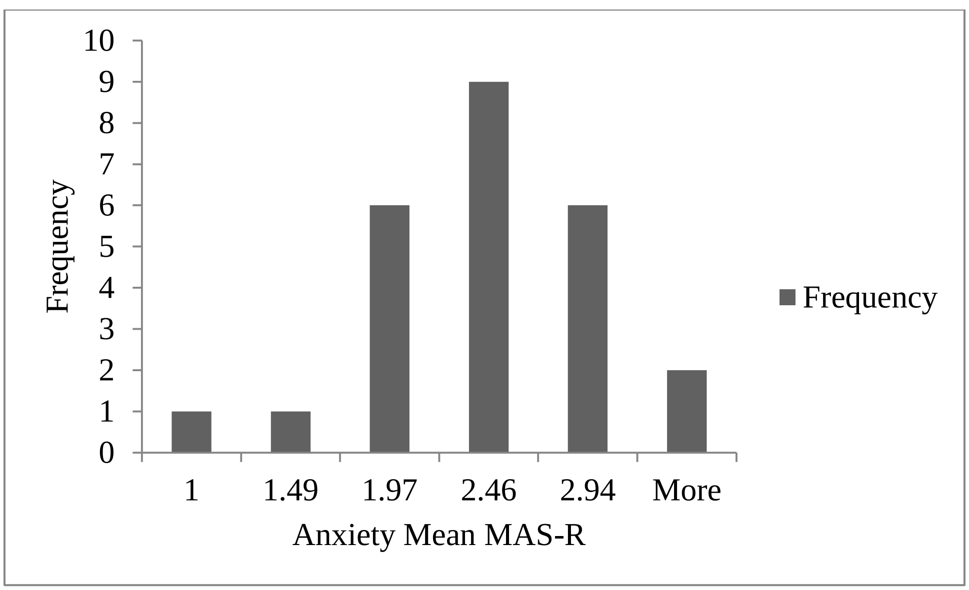


Figure 14. Histogram Post-Visit Control Group School A2

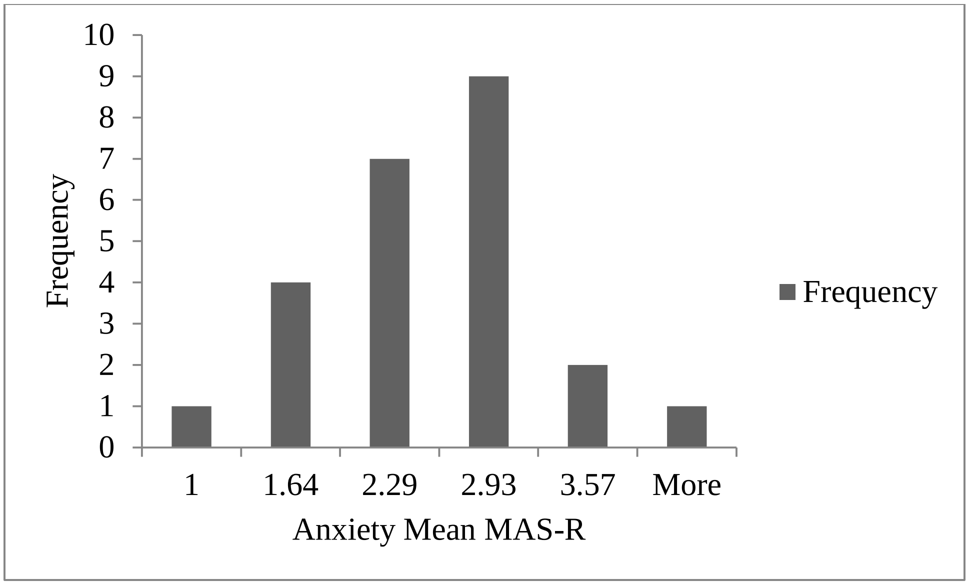


Figure 15. Histogram Post-Post-Visit Control Group School A2

To test for measureable change between repeated applications of the MAS-R, the researcher performed the ANOVA. The null hypothesis states there will be no difference in mean scores when comparing pre-test, post-test, and post-post-test for the treatment group of students. The p-value from the ANOVA test is .21 for the treatment group. With an alpha level of .05, the decision was not to reject the null hypothesis. The p-value from the ANOVA test is .70 for the control group. With an alpha level of .05, the decision was not to reject the null hypotheses. Table 11 shows the ANOVA results for the treatment group, and Table 12 shows the results for the control group of students.

Table 11

ANOVA: Single Factor School A2 Treatment Group

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	26	64.785714	2.4917582	0.7797253
Column 2	25	52.5	2.1	0.7427721
Column 3	23	48.071429	2.0900621	1.0140155

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	2.6528159	2	1.3264079	1.5793748	0.2132584	3.1257642
Within Groups	59.628003	71	0.839831			
Total	62.280819	73				

Note: A p-value of 0.21 > α (0.05) indicates the decision to not reject the null hypothesis.

Table 12

ANOVA: Single Factor School A2 Control Group

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	25	59.857143	2.3942857	0.5944388
Column 2	25	56.357143	2.2542857	0.3206122
Column 3	24	54.071429	2.2529762	0.4747024

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	0.3274602	2	0.1637301	0.3535602	0.703413	3.1257642
Within Groups	32.879379	71	0.4630898			
Total	33.206839	73				

Note: A p-value of 0.70 > α (0.05) indicates the decision to not reject the null hypothesis.

To test for measureable change between repeated applications of the MAS-R, pre-visit to post-visit, the researcher performed the t Test for difference in means. The null hypothesis states the post-test results on the MAS-R will not be less than pre-test results for the treatment group of students. The p-value is .06. With an alpha level of .05, the decision was to not reject the null hypothesis. The p-value indicates the likelihood or probability of obtaining these same test values if the null hypothesis is true. Table 13 shows the t Test results.

Table 13

t Test School A2 Treatment Group Pre-Visit to Post-Visit

	Variable 1	*Variable 2*
Mean	2.491758242	2.1
Variance	0.779725275	0.742772109
Observations	26	25
Pooled Variance	0.761625765	
Hypothesized Mean Difference	0	
df	49	
t Stat	1.602577048	
P(T<=t) one-tail	0.057727854	
t Critical one-tail	1.676550893	

Note: A p-value of 0.057 > α (0.05) indicates the decision to not reject the null hypothesis.

To test for measureable change between repeated applications of the MAS-R, post-visit to post-post visit the t Test for difference in means was performed. The null hypothesis states the post-post test results on the MAS-R will not be less than post-test results for the treatment group of students. The p-value is .49. With an alpha level of .05, the decision was not to reject the null hypothesis. The p-value indicates the likelihood or probability of obtaining these same test values if the null hypothesis is true. Table 14 shows the t Test results.

Table 14

t Test School A2 Treatment Group Post-Visit to Post-Post-Visit

	Variable 1	*Variable 2*
Mean	2.1	2.090062112
Variance	0.742772109	1.014015488
Observations	25	23
Pooled Variance	0.872497203	
Hypothesized Mean Difference	0	
df	46	
t Stat	0.036823527	
P(T<=t) one-tail	0.485392528	
t Critical one-tail	1.678660414	

Note: A p-value of 0.48 > α (0.05) indicates the decision to not reject the null hypothesis.

Concept Knowledge Map Results. Figure 16 and Figure 17 summarize the qualitative data for each administration of the concept knowledge map pre-visit, post visit, and post-post-visit for the treatment and control groups from School A2. A decrease in Attitude Negative responses was observed in the treatment group between pre-visit and post-visit testing. Pre-visit responses were 5.5% and post-visit responses were 3.1%. The responses from the post-post-visit testing increased to 11.9%. An increase in Attitude Positive was observed. Pre-visit student responses were 13.1%, post-visit responses 55.8%, and post-post-visit responses were 49.8%. The percentage of Number Operation responses decreased in the treatment group. The pre-visit responses were 27.5%, 6.7% post-visit, and 8.5% post-post-visit. The percentage of responses in Algebra, Data and Probability, Geometry, and Measurement varied from pre-visit to post-visit and post-post-visit. All decreased from pre-visit to post-visit and post-visit to post-post-visit.

The School A2 control group's responses did not fluctuate like the treatment group from School A2. The control group's Number Operation responses increased from

63.6% pre-visit to 64.7% post-visit and increased at the post-post visit administration to 72.9%. The percentage of Attitude Negative responses went from 3.1% pre-visit to 2.5% post-visit and remained unchanged at the post-post-session. Attitude Positive responses increased from 4.0% pre-visit to 10.4% post-visit. Algebra, Geometry, and Measurement responses varied slightly while Data and Probability increased from 6.2% pre-visit to 7.4% post-visit and then decreased to 2.5% on the post-post-administration of the instrument.

These results indicated that the students in the treatment group understanding of mathematics as a diverse body of topics changed from the visit to the Math Center. The students' perceptions of math as adding, subtracting, multiplying, and dividing decreased but the other strands did not evidence an increase. The results indicated that the treatment group of students' attitude shifted greatly to a positive view of mathematics. The control group results were anticipated as it was expected that the results of the control group would not fluctuate.

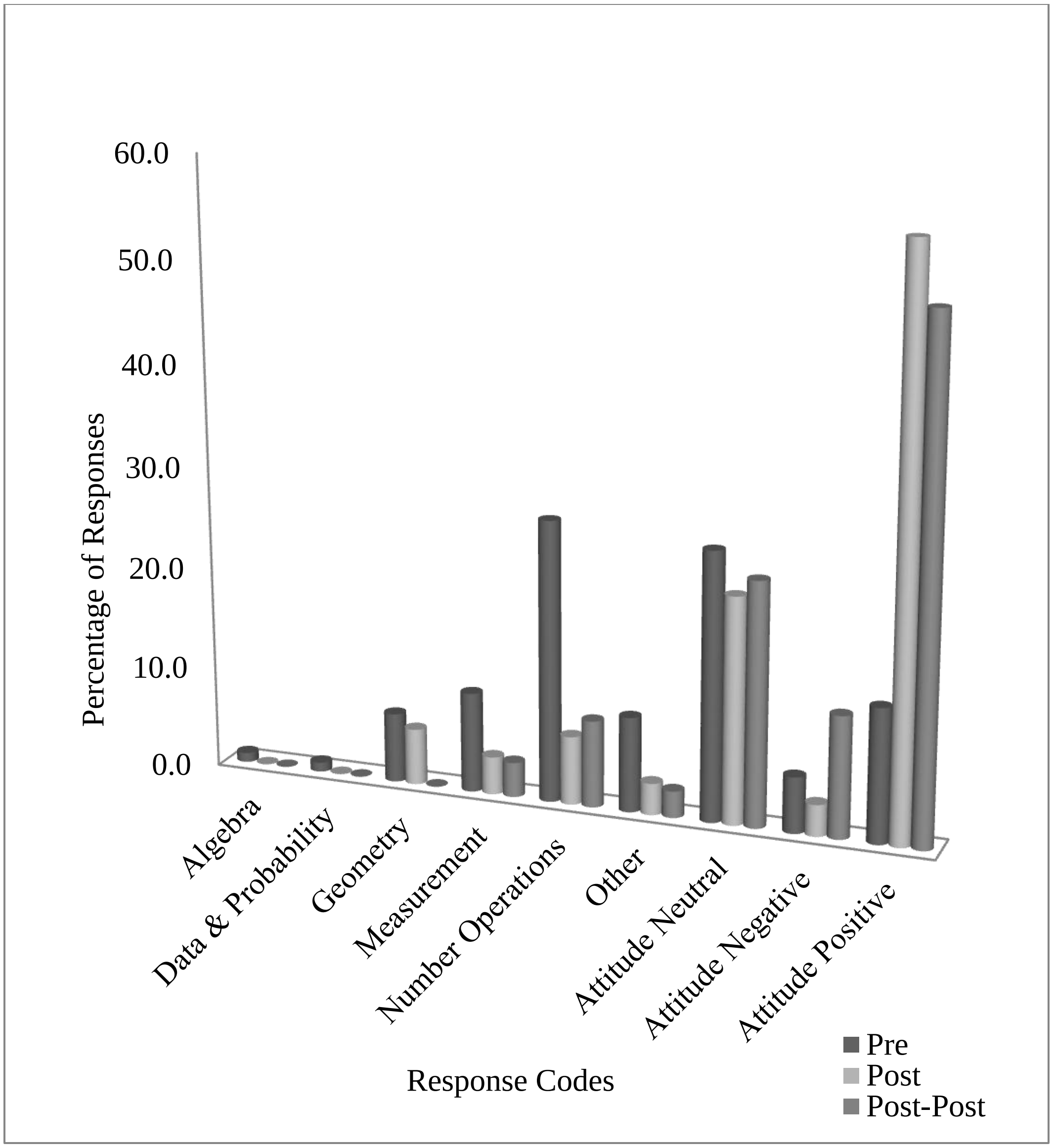


Figure 16. Student Responses Concept Knowledge Map School A2 Treatment Group – All Testing Sessions

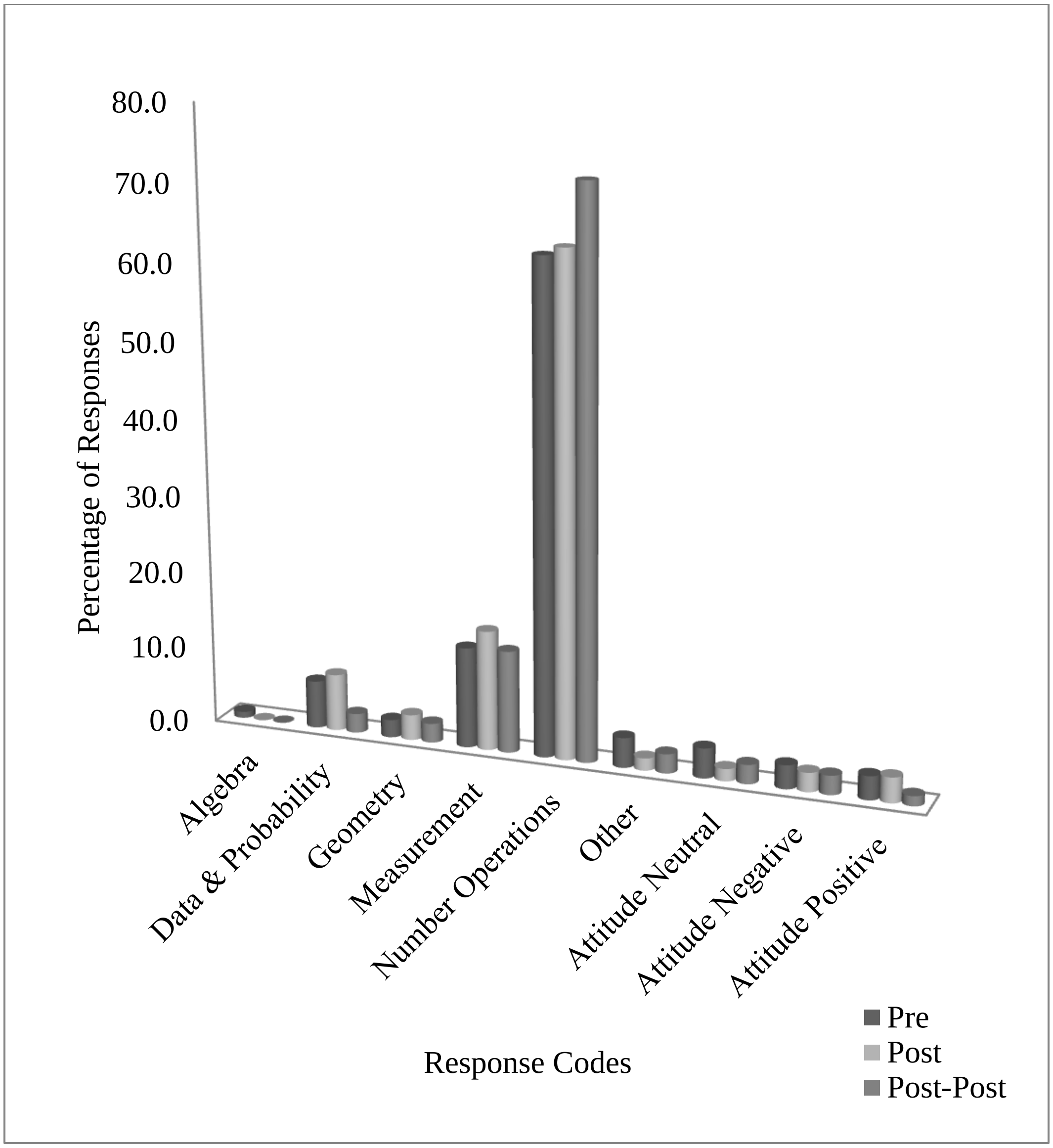


Figure 17. Student Responses Concept Knowledge Map School A2 Control Group – All Testing Sessions

Observations of Independent Evaluator. The independent evaluator observed 14 participants or groups of participants in the third grade treatment group from School A2. The observer reported the participants did not read or follow directions and many times created their own rules and directions when interacting with the exhibit. Participants were engaged in all activities and played with each exhibit or activity at a level that was appropriate for the individual. The evaluator reported that one student was frustrated with the Simply Amazing, a giant maze that involved teamwork, activity and moved on quickly to another activity. The evaluator reported that “the [car] robots were not the favorite today.” The students program the robots to make squares and rectangles, put a marker in the robot, press “go”, observe the results, and then problem-solve and reprogram as necessary.

The kindergarten class from School A2 visited with the third grade students but did not participate in the study. At the end of the visit, the “buddies” accompanied the participants for an additional half-hour in the Math Center. The third graders were to guide their kindergarten “buddy” to activities in the Math Center. The evaluator noted that the Yellow Room with the art projects was the most popular starting room as the kids made mosaics and used the spin markers, and the arrangement “Seemed to work for some, but for others, the third grader just took the kindergarten student to what they wanted to do”.

District B, School 3, First Grade, Class A – One Group Design

MAS-R Results. Table 15 shows the MAS-R means for the first grade participants from School B3, Class A. In order to compare, analyze, and interpret the data from the students in the class to the teacher of the class, the MAS-R data from the students is above the MAS-R data from the teacher of the class in the table. The teacher and the students rated themselves with low anxiety levels on the pre-visit testing. The students demonstrated an increase; however, the teacher’s ratings did not change from pre-visit to post-visit. Table 16 shows the median for the first grade participants in Class A. The median anxiety score decreased at the same rate that the mean decreased.

Table 15

Summary of Mean Data – School B3, Class A

Group	Pre-Visit	Post Visit
First Grade A Students	2.06	1.87
First Grade A In-Service Teacher	1.21	1.21

Note: Means were calculated for each group that participated in the study. Means were calculated by assigning point values to the responses on the MAS-R. The highest rating score possible was five and the lowest rating score was one.

Table 16

Summary of Median Data – School B3, Class A

Group	Pre-Visit	Post Visit
Treatment - Students	1.64	1.43

Note: The median MAS-R scores were calculated for each group that participated in the study. The medians were calculated from the means of each student's anxiety rating on the MAS-R in the class. The highest rating score on the MAS-R possible was five and the lowest rating score was one.

The histograms in Figure 18 and Figure 19 indicated the frequency and distribution of the MAS-R scores for the School B3, Class A group. The frequency of scores demonstrated how the mean scores lessened after the visit to the Math Center, indicating a lessening of math anxiety. The histograms provided evidence about how the anxiety level means decreased from pre-visit to post-visit. No lessening in anxiety was demonstrated for this class of first grade students.

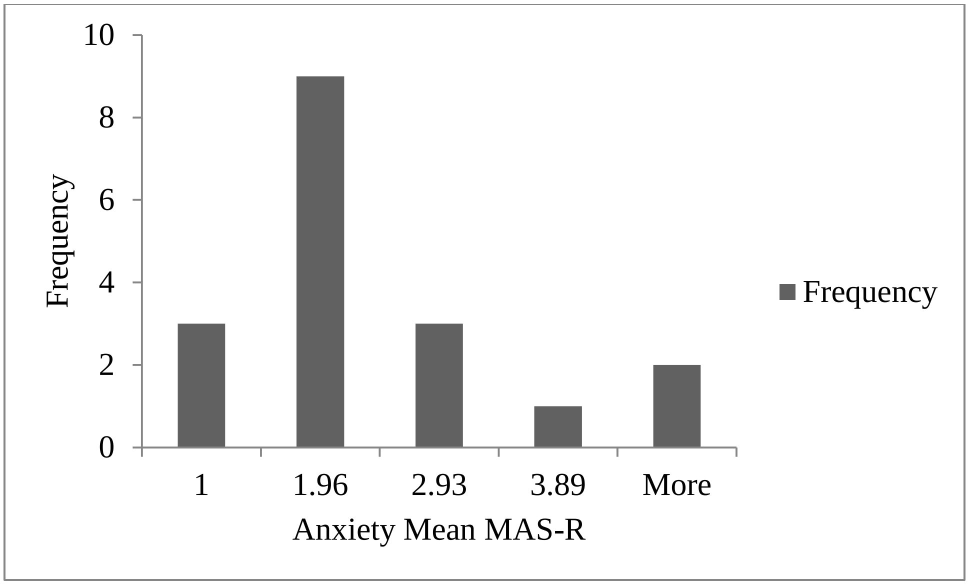


Figure 18. Histogram Pre-Visit School B3, Class A

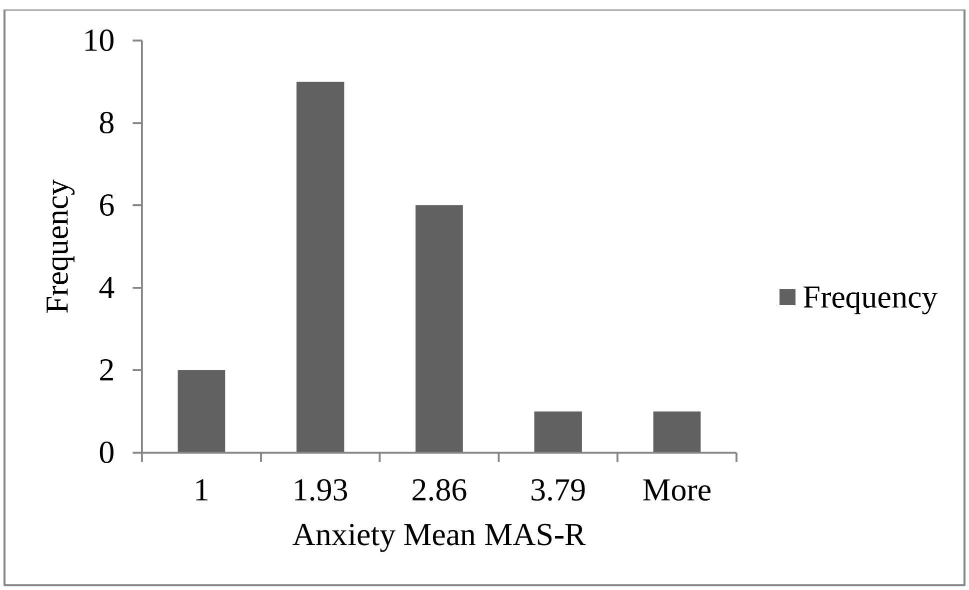


Figure 19. Histogram Post-Visit School B3, Class A

To test for measureable change between repeated applications of the MAS-R, pre-visit to post-visit the t Test for difference in means was performed. The null hypothesis states the post-test results on the MAS-R will not be less than pre-test results for the

treatment group of students. The p-value is .30. With an alpha level of .05, the decision was not to reject the null hypothesis. The p-value indicates the likelihood or probability of obtaining these same test values if the null hypothesis is true. Table 17 shows the t Test results.

Table 17

t Test School B3, Class A – Pre-Visit to Post-Visit

	Variable 1	*Variable 2*
Mean	2.063492063	1.879699248
Variance	1.39789249	0.832796276
Observations	18	19
Pooled Variance	1.10727158	
Hypothesized Mean Difference	0	
df	35	
t Stat	0.531023383	
P(T<=t) one-tail	0.299378248	
t Critical one-tail	1.68957244	

Note: A p-value of 0.29 > α (0.05) indicates the decision to not reject the null hypothesis.

Concept Knowledge Map Results. Figure 20 summarizes the qualitative data for the administration of the concept knowledge map pre-visit and post-visit from School B3, Class A. A decrease in Attitude Negative responses was observed between pre-visit and post-visit testing. Pre-visit responses were 13.8% and post-visit responses were 12.4%. An increase in Attitude Neutral responses was observed. Pre-visit student responses were 15.0%, while post-visit responses were 19.8%. Attitude Positive responses decreased from 71.2% pre-visit to 65.4% post-visit. These students had no responses in the categories of Algebra, Data and Probability, Geometry, Measurement, and Number Operations during the pre-visit session. The percentage of Data and Probability responses increased to 1.2% at the post-visit session. These first grade students, for the most part, began with positive attitudes towards math and experienced little change from their visit to the Math Center.

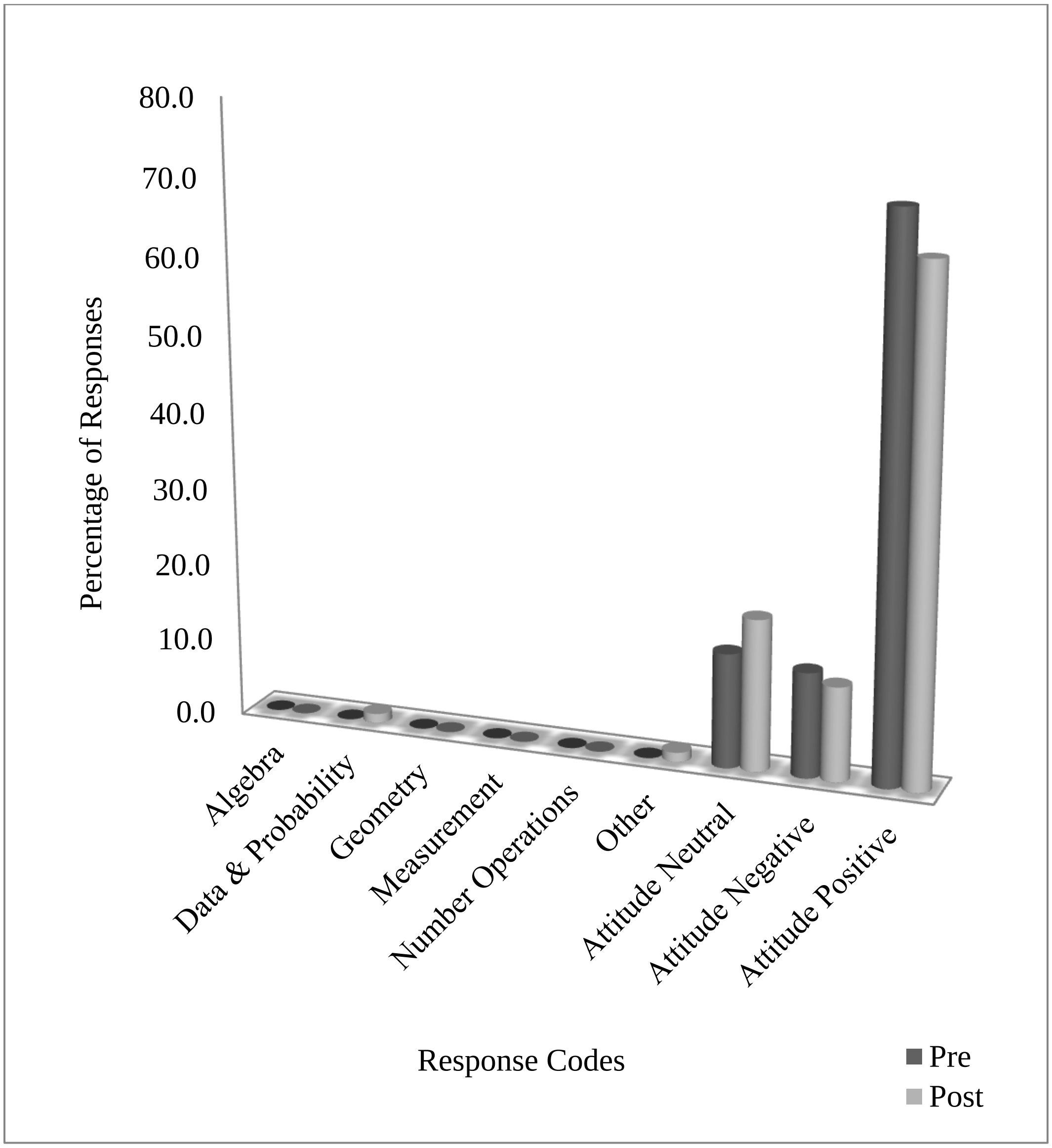


Figure 20. Student Responses Concept Knowledge Map School B3, Class A – All Testing Sessions

Observations of Independent Evaluator. The observations from School B3, Class A will be discussed after School B3, Class C as Class A, Class B, and Class C visited the Math Center during the same field trip experience.

District B, School 3, First Grade, Class B – One Group Design

MAS-R Results. Table 18 shows the MAS-R means for the first grade participants from School B3, Class B. In order to compare, analyze, and interpret the data from the students in the class to the teacher of the class, the MAS-R data from the students is above the MAS-R data from the teacher of the class in the table. The means demonstrate a lessening in anxiety from pre-visit to post-visit administration. Table 19 shows the median for the first grade participants in Class B. The median anxiety score decreased at the same rate that the mean decreased.

Table 18

Summary of Mean Data – School B3, Class B

Group	Pre-Visit	Post Visit
First Grade B Students	2.90	2.50
First Grade B In-Service Teacher	1.93	1.43

Note: Means were calculated for each group that participated in the study. Means were calculated by assigning point values to the responses on the MAS-R. The highest rating score possible was five and the lowest rating score was one.

Table 19

Summary of Median Data – School B3, Class B

Group	Pre-Visit	Post Visit
Treatment - Students	3.04	2.57

Note: The median MAS-R scores were calculated for each group that participated in the study. The medians were calculated from the means of each student's anxiety rating on the MAS-R in the class. The highest rating score on the MAS-R possible was five and the lowest rating score was one.

The histograms in Figure 21 and Figure 22 indicated the frequency and distribution of the MAS-R scores for the School B3, Class B group. The frequency of scores demonstrated how the mean scores lessened after the visit to the Math Center. The histograms also demonstrate that the median scores of the means decreased at approximately the same interval as the mean scores. The histograms provided evidence about how the anxiety level means decreased from pre-visit to post-visit. A lessening in anxiety was further demonstrated when the histogram illustrated more of a positive or right-skewed distribution.

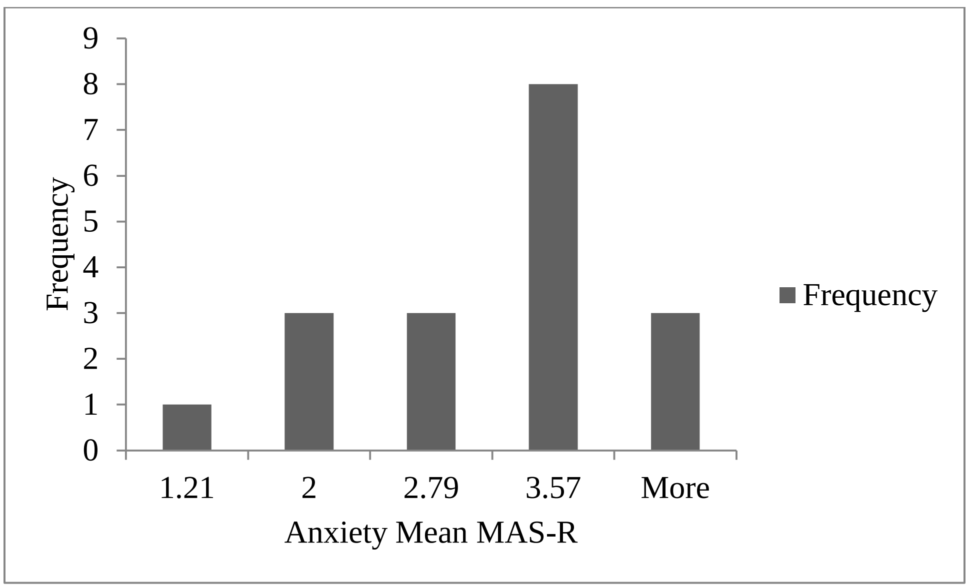


Figure 21. Histogram Pre-Visit School B3, Class B

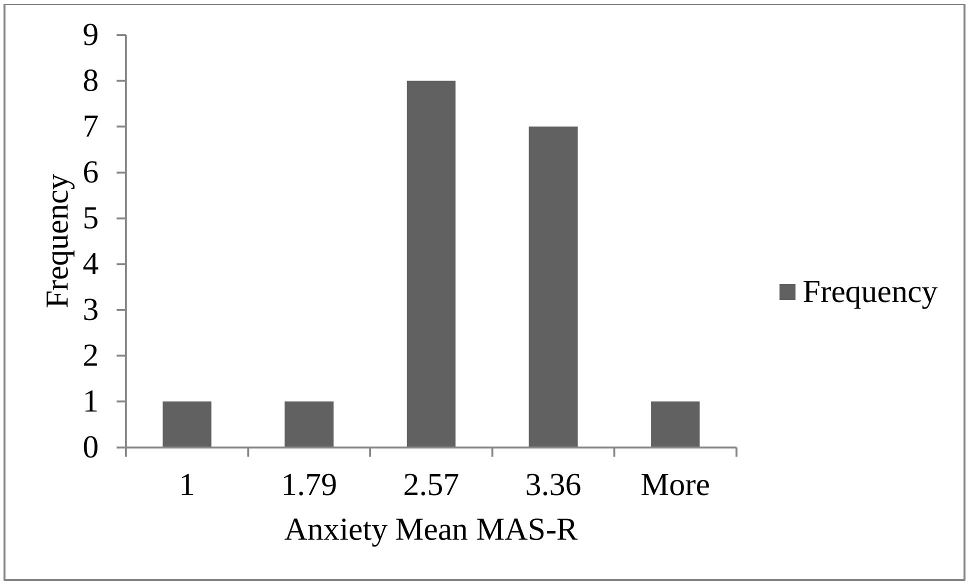


Figure 22. Histogram Post-Visit School B3, Class B

To test for measureable change between repeated applications of the MAS-R, pre-visit to post-visit the t Test for difference in means was performed. The null hypothesis states the post-test results on the MAS-R will not be less than pre-test results for the treatment group of students. The p-value is .08. With an alpha level of .05, the decision was not to reject the null hypothesis. The p-value indicates the likelihood or probability of obtaining these same test values if the null hypothesis is true. Table 20 shows the t Test results.

Table 20

t Test School B3, Class B – Pre-Visit to Post-Visit

	Variable 1	*Variable 2*
Mean	2.904761905	2.496031746
Variance	0.854141657	0.58311658
Observations	18	18
Pooled Variance	0.718629118	
Hypothesized Mean Difference	0	
df	34	
t Stat	1.446457019	
P(T<=t) one-tail	0.078602877	
t Critical one-tail	1.690924198	

Note: A p-value of 0.07 > α (0.05) indicates the decision to not reject the null hypothesis.

Concept Knowledge Map Results. Figure 23 summarizes the qualitative data for the administration of the concept knowledge map pre-visit and post visit from School B3, Class B. An increase in Attitude Negative responses was observed between pre-visit and post-visit testing. Pre-visit responses were 2.0% and post-visit responses were 5.4%. An increase in Attitude Positive was observed. Pre-visit student responses were 11.9%, while post-visit responses were 16.2%. Attitude Neutral responses decreased from 17.8% pre-visit to 12.1% post-visit. These students had varied responses in the categories of Algebra, Data and Probability, Geometry, Measurement, and Number Operations during the pre-visit and post-visit sessions. The percentage of Measurement responses decreased from 18.8% to 10.8% at the post-visit session. These results indicated that the students understanding of mathematics as a diverse body of topics did not change from the visit to the Math Center. The students continued to perceive math as adding, subtracting, multiplying, and dividing. The results indicated that the students' attitude shifted slightly to a more positive view of mathematics.

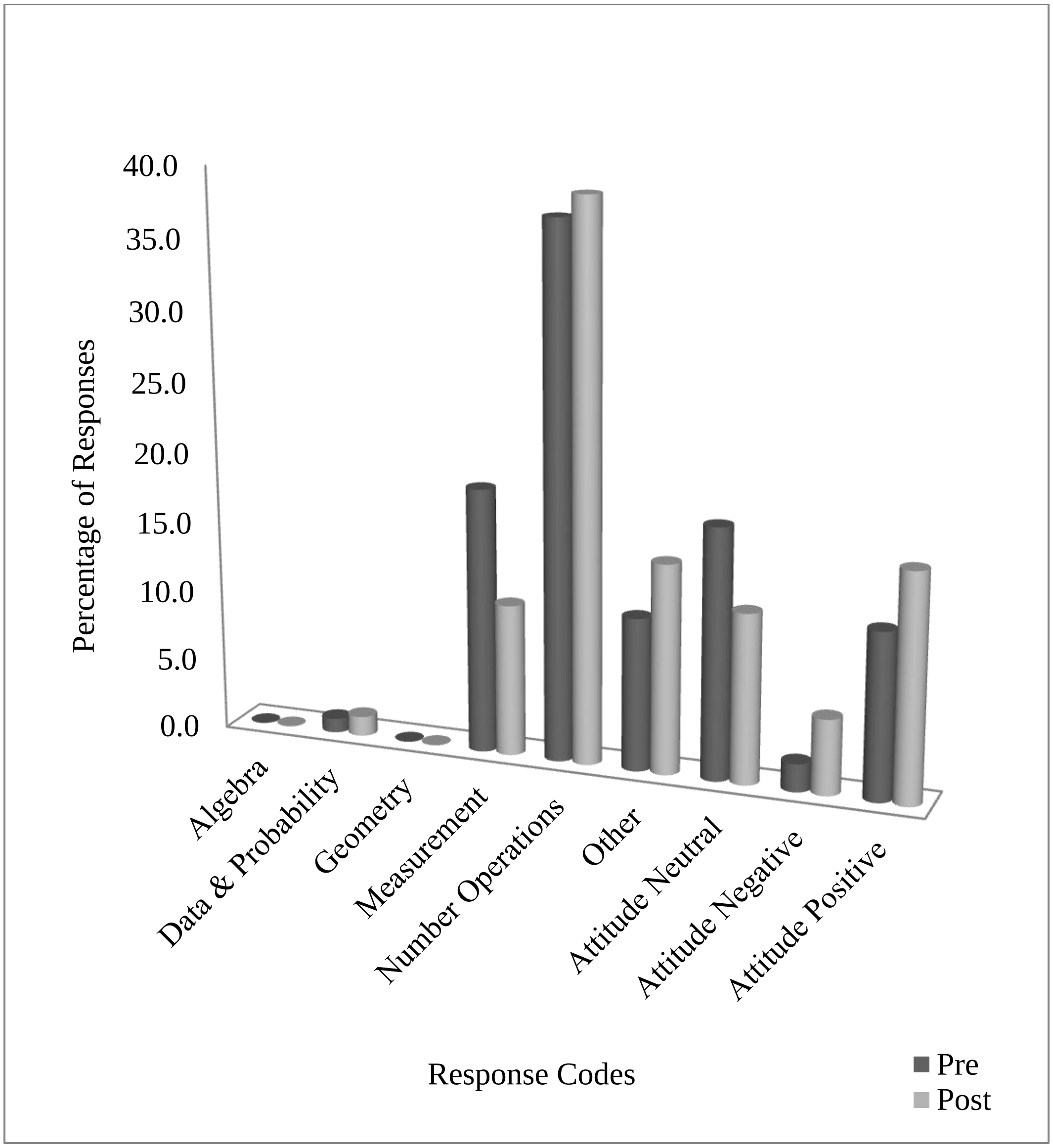


Figure 23. Student Responses Concept Knowledge Map School B3, Class B – All Testing Sessions

Observations of Independent Evaluator. The observations from School B3, Class B will be discussed after School 3, Class C as Class A, Class B, and Class C visited the Math Center during the same field trip experience.

District B, School 3, First Grade, Class C – One Group Design

MAS-R Results. Table 21 shows the MAS-R means for the first grade participants from School B3, Class C. In order to compare, analyze, and interpret the data from the students in the class to the teacher of the class, the MAS-R data from the students is above the MAS-R data from the teacher of the class in the table. The means demonstrate a lessening in anxiety from pre-visit to post-visit administration. Table 22 shows the median for the first grade participants in Class C. The median anxiety score decreased at the same rate that the mean decreased.

Table 21

Summary of Mean Data – School B3, Class C

Group	Pre-Visit	Post Visit
First Grade C Students	2.47	2.27
First Grade C In-Service Teacher	2.71	2.57

Note: Means were calculated for each group that participated in the study. Means were calculated by assigning point values to the responses on the MAS-R. The highest rating score possible was five and the lowest rating score was one.

Table 22

Summary of Median Data – School B3, Class C

Group	Pre-Visit	Post Visit
Treatment - Students	2.50	2.29

Note: The median MAS-R scores were calculated for each group that participated in the study. The medians were calculated from the means of each student's anxiety rating on the MAS-R in the class. The highest rating score on the MAS-R possible was five and the lowest rating score was one.

The histograms in Figure 24 and Figure 25 indicated the frequency and distribution of the MAS-R scores for the School B3, Class C group. The frequency of scores demonstrated how the mean scores lessened after the visit to the Math Center. The histograms also demonstrate that the median scores of the means decreased at approximately the same interval as the mean scores.

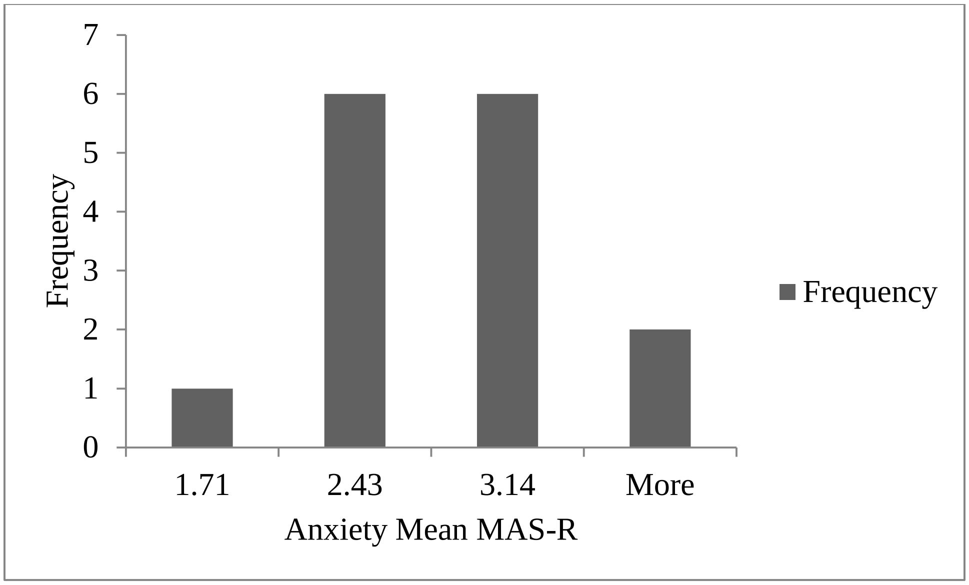


Figure 24. Histogram Pre-Visit School B3, Class C

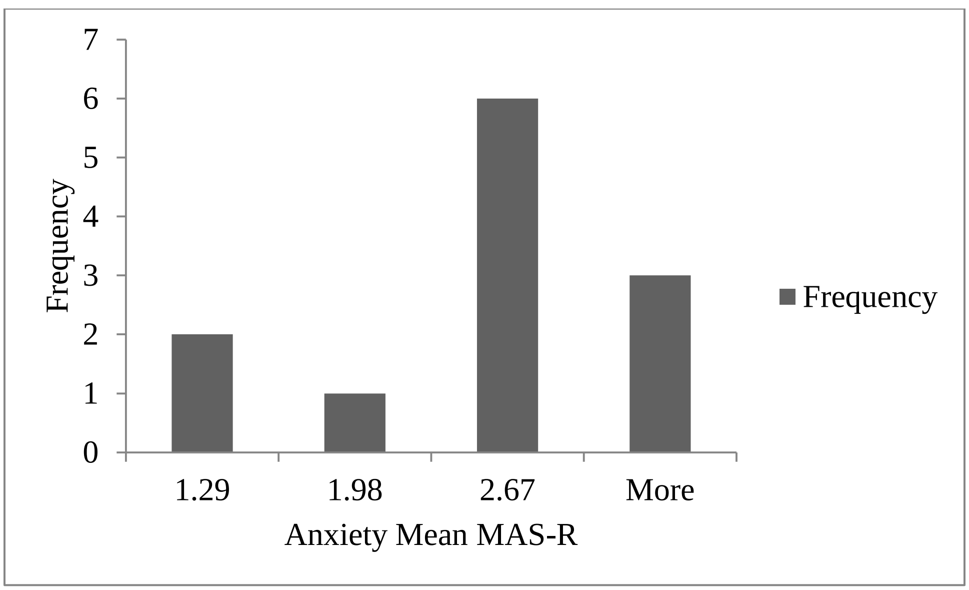


Figure 25. Histogram Post-Visit School B3, Class C

To test for measureable change between repeated applications of the MAS-R, pre-visit to post-visit the t Test for difference in means was performed. The null hypothesis states the post-test results on the MAS-R will not be less than pre-test results for the

treatment group of students. The p-value is .21. With an alpha level of .05, the decision was not to reject the null hypothesis. The p-value indicates the likelihood or probability of obtaining these same test values if the null hypothesis is true. Table 23 shows the t Test results.

Table 23

t Test School B3, Class C – Pre-Visit to Post-Visit

	Variable 1	*Variable 2*
Mean	2.471428571	2.273809524
Variance	0.416763848	0.386672851
Observations	15	12
Pooled Variance	0.40352381	
Hypothesized Mean Difference	0	
df	25	
t Stat	0.803246034	
P(T<=t) one-tail	0.214701895	
t Critical one-tail	1.708140745	

Note: A p-value of 0.21 > α (0.05) indicates the decision to not reject the null hypothesis.

Concept Knowledge Map Results. Figure 26 summarizes the qualitative data for the administration of the knowledge concept map pre-visit and post-visit from School B3, Class C. No Attitude Negative responses were observed at either the pre-visit or post-visit testing. An increase in Attitude Positive was observed. Pre-visit student responses were 46.4%, while post-visit responses were 51.1%. Attitude Neutral responses decreased from 21.0% pre-visit to 8.9% post-visit. These students had varied responses in the categories of Algebra, Data and Probability, Geometry, and Measurement. Geometry responses increased from 1.5% to 4.4%, and Measurement responses increased from 0% to 8.9%. Number Operation responses decreased from 10.1% at the pre-visit session to 2.2% at the post-visit session. These results indicated that the students' understanding of mathematics as a diverse body of topics did change from the visit to the Math Center as a decrease in Number Operations and an increase in Geometry and Measurement is demonstrated. The results indicated that the students' attitude shifted slightly to a more positive view of mathematics.

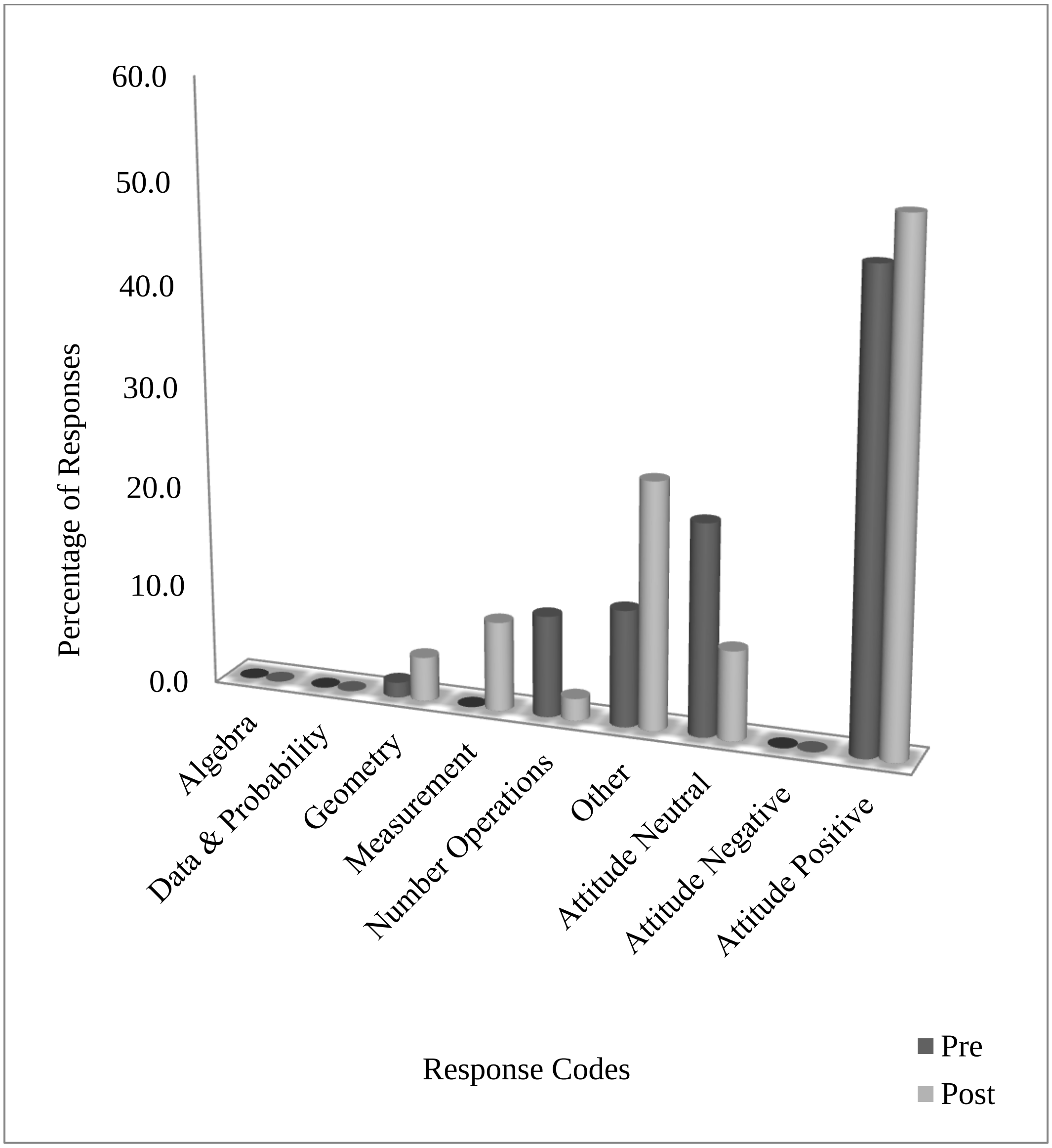


Figure 26. Student Responses Concept Knowledge Map School B3, Class C – All Testing Sessions

Observations of Independent Evaluator. The independent evaluator had observed several field trips and had noticed the visitors during the site speech, and noted that the site speech for this visit lasted 18 minutes. The evaluator observed 10 participants or groups of participants during the field trip visit of the first grade classes from School B3. The evaluator noted that the students did not read or follow directions and commented, “Perhaps because most were not that good [as first grade students] at reading yet.” The directions were written at different levels, but depending on the exhibit, ranged between a third to a sixth grade level. In nine of the ten observations, the evaluator observed the participants making up their own rules and interacting with the activities typical to first grade behaviors. This is not uncommon in a free-choice institution. The visitor decides how he/she interacts with an exhibit. In addition, first grade students are exploring trying to make sense of the world and this would be typical first grade behavior. The exception was an activity in the Young Child area, the area designed specifically for pre-kindergarten to second grade students, where the students were asked to pack a suitcase based on a given weather situation. The students at this activity independently participated and completed the activity. The evaluator ended his report stating the participants were connected, curious, adventuresome, and interested in trying the activities.

District B, School 3, Third Grade – One Group Design

MAS-R Results. Table 24 the MAS-R means for the third grade participants from School B3. In order to compare, analyze, and interpret the data from the students in the class to the teacher of the class, the MAS-R data from the students is above the MAS-R data from the teacher of the class in the table. The means do not demonstrate a lessening in anxiety from pre-visit to post-visit administration. Table 25 shows the median for the third grade participants. The median anxiety score decreased from pre-visit to post-visit testing.

Table 24

Summary of Mean Data – School B3, Third Grade

Group	Pre-Visit	Post Visit
Third Grade Students	2.24	2.24
Third Grade In-Service Teacher	2.29	2.07

Note: School 3 participated in the study without a control. Means were calculated for each group that participated in the study. Means were calculated by assigning point values to the responses on the MAS-R. The highest rating score possible was five and the lowest rating score was one.

Table 25

Summary of Median Data – School B3, Third Grade

Group	Pre-Visit	Post Visit
Treatment - Students	2.43	2.21

Note: The median MAS-R scores were calculated for each group that participated in the study. The medians were calculated from the means of each student's anxiety rating on the MAS-R in the class. The highest rating score on the MAS-R possible was five and the lowest rating score was one.

The histograms in Figure 27 and Figure 28 indicated the frequency and distribution of the MAS-R scores for the School B3, third grade group. The frequency of scores demonstrated the distribution of the mean scores pre and post visit to the Math Center. Although the mean did not change from pre to post visit, the histograms demonstrated that the median scores of the means decreased.

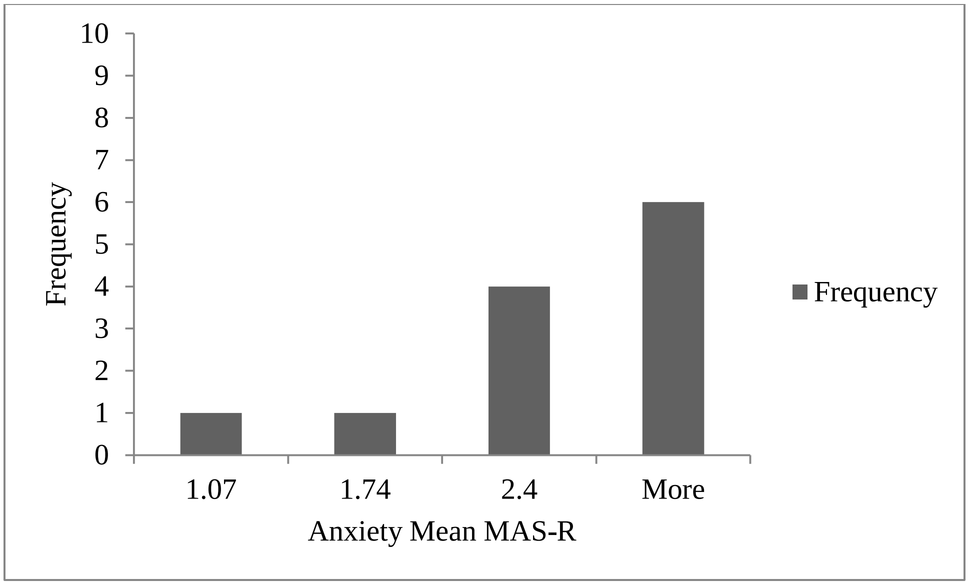


Figure 27. Histogram Pre-Visit School B3, Third Grade

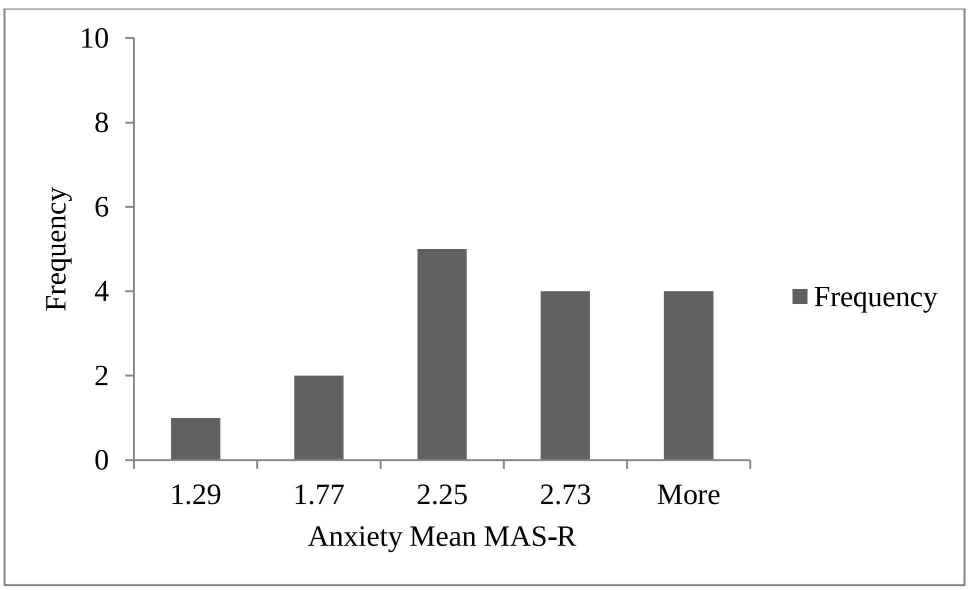


Figure 28. Histogram Post-Visit School B3, Third Grade

To test for measureable change between repeated applications of the MAS-R, pre-visit to post-visit the t Test for difference in means was performed. The null hypothesis states the post-test results on the MAS-R will not be less than pre-test results for the

treatment group of students. The p-value is .49. With an alpha level of .05, the decision was not to reject the null hypothesis. The p-value indicates the likelihood or probability of obtaining these same test values if the null hypothesis is true. Table 26 shows the t Test results.

Table 26

t Test School B3, Third Grade – Pre-Visit to Post-Visit

	Variable 1	*Variable 2*
Mean	2.244047619	2.241071429
Variance	0.42435838	0.29787415
Observations	12	16
Pooled Variance	0.351386709	
Hypothesized Mean Difference	0	
df	26	
t Stat	0.013147393	
P(T<=t) one-tail	0.494805284	
t Critical one-tail	1.705617901	

Note: A p-value of 0.49 > α (0.05) indicates the decision to not reject the null hypothesis.

Concept Knowledge Map Results. Figure 29 summarizes the qualitative data for the administration of the knowledge concept map pre-visit and post-visit for the third grade class from School B3. Attitude Negative responses observed between pre-visit and post-visit testing did not change. An increase in Attitude Positive was observed. Pre-visit student responses were 3.6%, while post-visit responses were 9.7%. Attitude Neutral responses did not change between pre and post visits. The third grade had varied responses in the categories of Algebra, Data and Probability, and Geometry. These three categories did not change significantly from pre to post-visit. However, Number Operations and Measurement changed significantly. Number Operation responses increased from 30.1% to 40.3%, and Measurement responses decreased from 25.0% to 10.2%. These results indicated that the students' understanding of mathematics as a diverse body of topics was affected from the visit to the Math Center. The students began to perceive math as adding, subtracting, multiplying, and dividing. The results indicated that the treatment group of students' attitude changed to a more positive view of mathematics. It is possible that the topic of math instruction in the classroom and MAP testing had an influence on the students and thus the results.

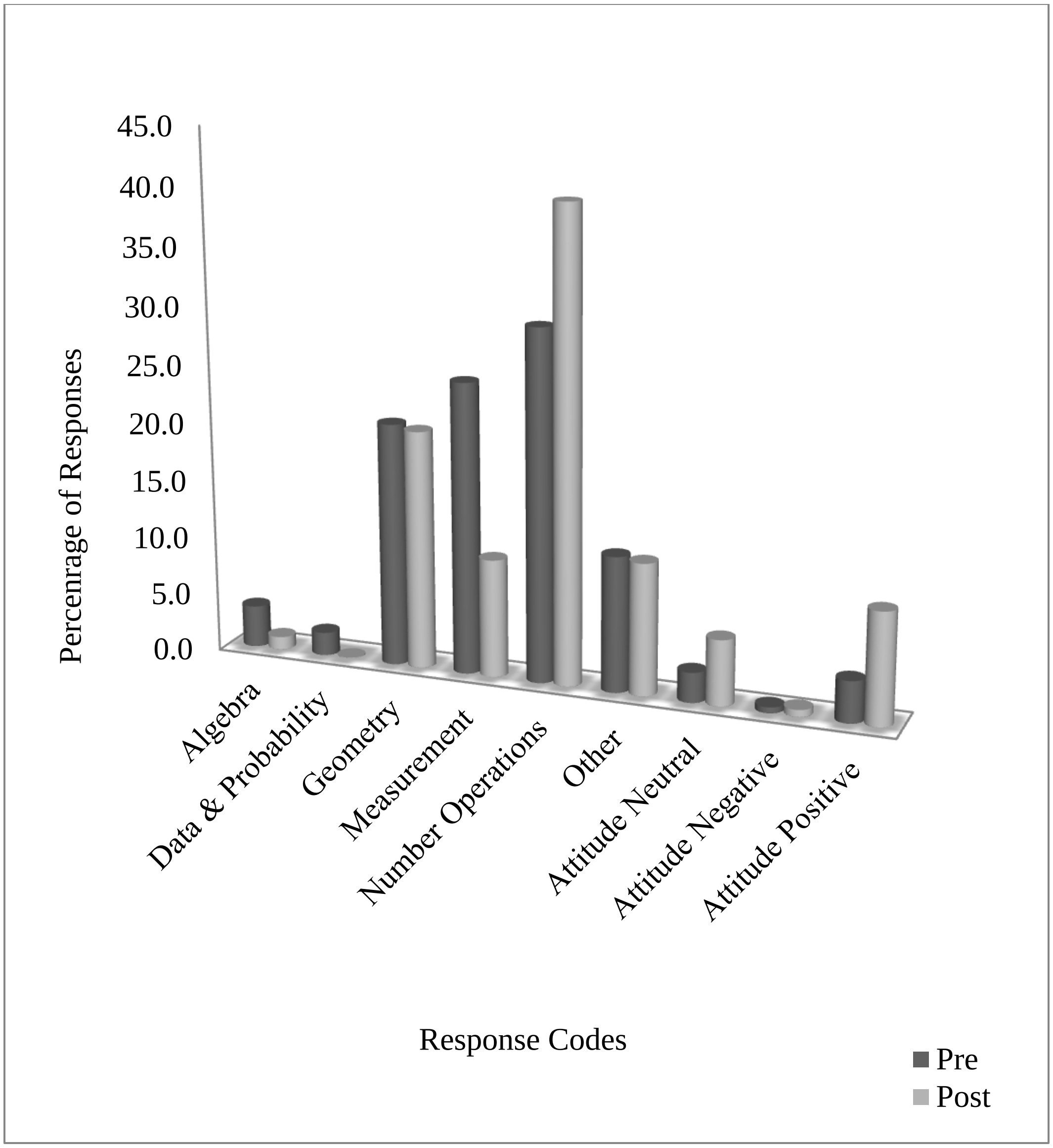


Figure 29. Student Responses Concept Knowledge Map School B3, Third Grade – All Testing Sessions

Observations of Independent Evaluator. The independent evaluator timed the site speech for the visit at 30 minutes and commented that it was too long and the parents were getting anxious. He noted that the parents reported they were assigned to rooms and stayed in their assigned rooms for all rotations. He added, “They seemed to feel more competent with each new group who came to their room. Interactions seemed to be better as they felt more confident about the activities." The evaluator observed 10 different participants or groups of participants. He noted that the students did not read the directions but were successful at the activities. The evaluator noted that the parents facilitated and worked with the students at the activities. The ProBots, robot cars, were a favorite with the students.

District A Results

MAS-R Results. Tables 27 and 28 show the results for the treatment and control groups from the z Test for difference in means which tests the change between repeated applications of the MAS-R, pre-visit to post-visit, and from post-visit to post-post visit. The null hypothesis states the post-test results on the MAS-R will not be less than pre-test results for the treatment group of students. The p-value from pre-visit to post-visit is .07. With an alpha level of .05, the decision was not to reject the null hypothesis. Table 27 shows the z Test results. The p-value from post-visit to post-post visit is .54. With an alpha level of .05, the decision was not to reject the null hypothesis. The p-value indicates the likelihood or probability of obtaining these same test values if the null hypothesis is true. Table 28 shows the z Test results.

Table 27

z Test District A – Pre-Visit to Post-Visit

	Variable 1	*Variable 2*
Mean	2.410714286	2.158571429
Known Variance	0.773797	0.696332
Observations	48	50
Hypothesized Mean Difference	0	
z	1.454598523	
P(Z<=z) one-tail	0.07289022	
z Critical one-tail	1.644853627	

Note: A p-value of 0.07 > α (0.05) indicates the decision to not reject the null hypothesis.

Table 28

z Test District A – Post-Visit to Post-Post-Visit

	Variable 1	*Variable 2*
Mean	2.158571429	2.066445183
Known Variance	0.66	0.7
Observations	50	43
Hypothesized Mean Difference	0	
z	0.536570123	
P(Z<=z) one-tail	0.295782293	
z Critical one-tail	1.644853627	

Note: A p-value of 0.29 > α (0.05) indicates the decision to not reject the null hypothesis.

To test for measureable change between repeated applications of the MAS-R, the ANOVA test was performed. The null hypothesis states there will be no difference in mean scores when comparing pre-test, post-test, and post-post-test for the treatment group of students. The p-value from the ANOVA test is .17 for the treatment group. With an alpha level of .05, the decision was not to reject the null hypothesis. The p-value from the ANOVA test is .70 for the control group. With an alpha level of .05, the decision was not to reject the null hypotheses. The p-value indicates the likelihood or probability of obtaining these same test values if the null hypothesis is true. Table 29 shows the ANOVA results for the treatment group, and Table 30 shows the results for the control group of students.

Table 29

ANOVA Test District A Treatment Group

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	47	112.64286	2.3966565	0.6647756
Column 2	50	107.92857	2.1585714	0.7047668
Column 3	43	88.857143	2.0664452	0.8912525

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	2.6558936	2	1.3279468	1.7741205	0.1735074	3.0622044
Within Groups	102.54586	137	0.7485099			
Total	105.20175	139				

Note: A p-value 0.17 > α (0.05) indicates the decision to not reject the null hypothesis.

Table 30

ANOVA Test District A Control Group

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	25	59.857143	2.3942857	0.5944388
Column 2	25	56.357143	2.2542857	0.3206122
Column 3	24	54.071429	2.2529762	0.4747024

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	0.3274602	2	0.1637301	0.3535602	0.703413	3.1257642
Within Groups	32.879379	71	0.4630898			
Total	33.206839	73				

Note: A p-value of 0.70 > α (0.05) indicates the decision to not reject the null hypothesis.

Concept Knowledge Map Results. Figure 30 summarizes the qualitative data for the administration of the concept knowledge map pre-visit, post visit, and post-post-visit for the District A Treatment Group. The total number of responses coded into each category for the treatment group from District A appears in Table 31. Attitude Negative responses observed between pre-visit and post-visit testing decreased from 5.41% to 1.78% and increased to 7.71% on the post-post visit administration. An increase in Attitude Positive was observed as pre-visit student responses were 12.47%, post-visit responses were 31.75%, and post-post visit responses increased to 35.21%. Attitude Neutral responses varied little between visits. District A demonstrated little change in responses for the categories of Algebra, Data and Probability, Geometry, and Measurement. However, Number Operations decreased from 38.59% to 32.34%, and to 28.53% post-post-visit. A decrease in Number Operations and an increase in the other response strands of mathematics indicated a change in understanding mathematics, and a decrease in negative attitude and an increase in positive attitude responses indicated the effectiveness of the Math Center visit. The results from the District A Treatment Group demonstrated a partial anticipated change in understanding mathematics and attitude.

Figure 31 summarizes the qualitative data for the administration of the concept knowledge map pre-visit, post visit, and post-post-visit for the District A Control Group. The control group demonstrated the anticipated results for a control group. Since the control group did not receive the treatment, the responses from each application of the concept knowledge map should not demonstrate change. This was the case for District A. The control group remained consistent while the treatment group demonstrated an increase in positive attitude and a change in understanding of mathematics with a decrease in Number Operation responses.

Table 31

Total Number of Responses in Each Category - Treatment Group District A

Response Category	Pre-Visit	Post-Visit	Post-Post Visit
Algebra	12	9	4
Data & Probability	4	2	6
Geometry	20	17	5
Measurement	30	14	11
Number Operations	164	109	111
Other	38	15	17
Attitude Neutral	81	58	68
Attitude Negative	23	6	30
Attitude Positive	53	107	137

Note: The total number of responses in each category for each administration of the concept knowledge map.

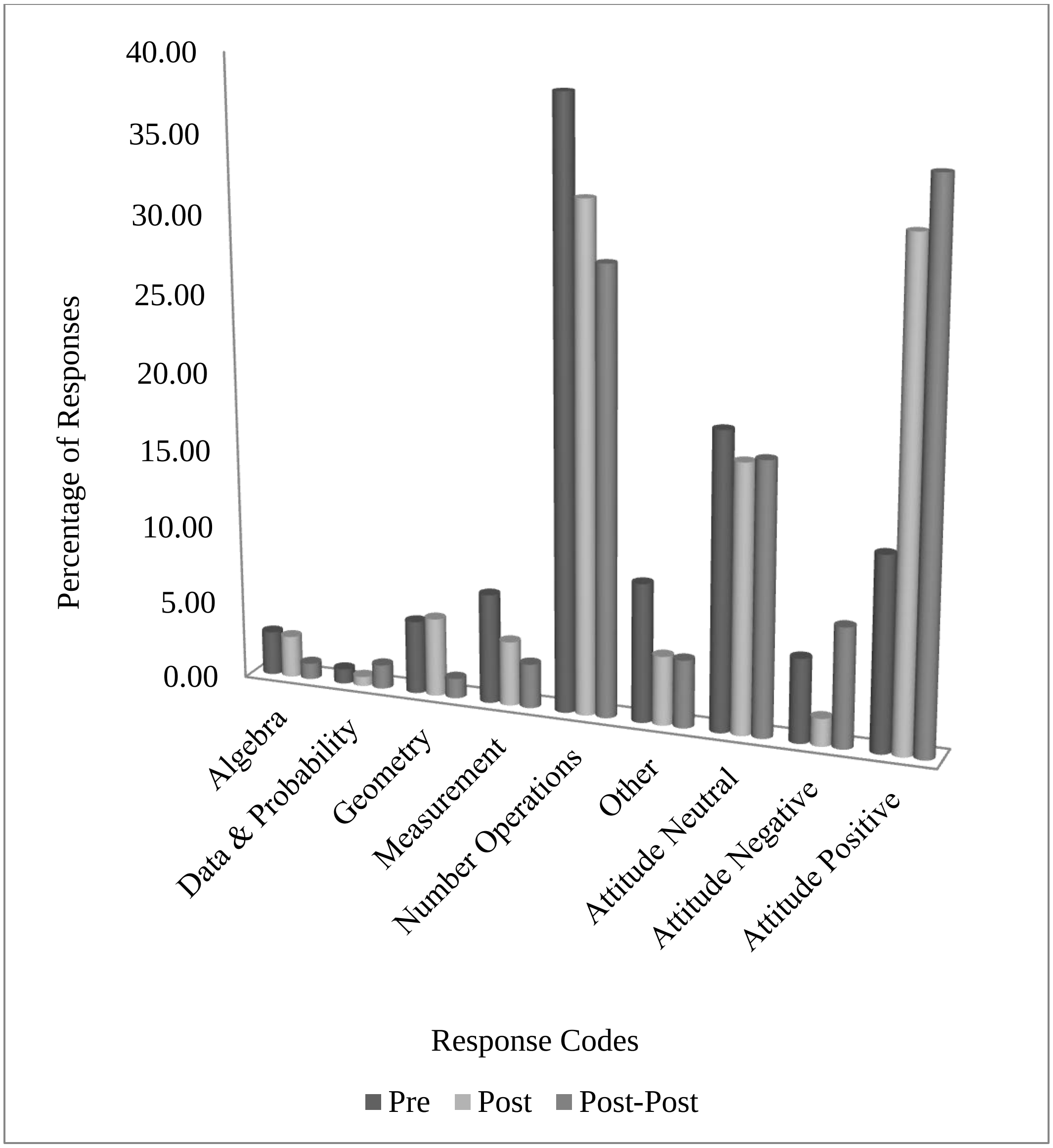


Figure 30. Student Responses Treatment Group Concept Knowledge Map District A – All Testing Sessions

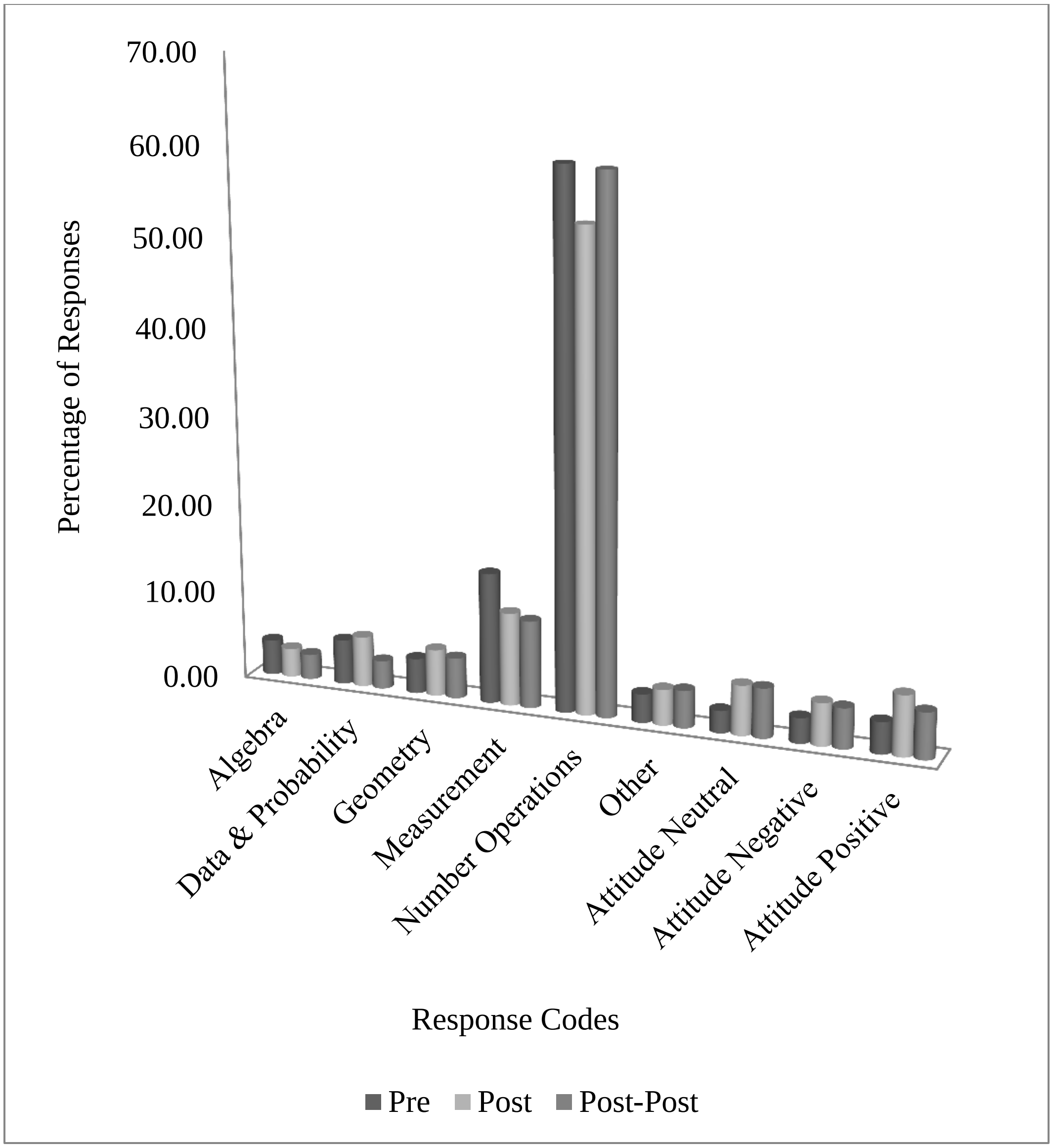


Figure 31. Student Responses Control Group Concept Knowledge Map District A – All Testing Sessions

District B Results

MAS-R Results. Table 32 shows the results of the z Test for difference in means which tests the change between repeated applications of the MAS-R, pre-visit to post-visit. The null hypothesis states the post-test results on the MAS-R will not be less than pre-test results for the treatment group of students. The p-value from pre-visit to post-visit is .07. With an alpha level of .05, the decision was not to reject the null hypothesis. The p-value indicates the likelihood or probability of obtaining these same test values if the null hypothesis is true.

Table 32

z Test District B – Pre-Visit to Post-Visit

	Variable 1	*Variable 2*
Mean	2.43537415	2.212087912
Known Variance	0.9	0.58
Observations	63	65
Hypothesized Mean Difference	0	
z	1.465668301	
P(Z<=z) one-tail	0.071369337	
z Critical one-tail	1.644853627	

Note: A p-value of 0.07 > α (0.05) indicates the decision to not reject the null hypothesis.

Concept Knowledge Map. Figure 32 summarizes the qualitative data from the concept knowledge map pre-visit and post-visit for School District B. The total number of responses coded into each category for the treatment group from District B appears in Table 33. Attitude Negative responses observed between pre-visit and post-visit testing changed slightly from 12.56% on the pre-visit to 10.37% on the post-visit session. An increase in Attitude Positive was observed as pre-visit student responses were 24.22%, while post-visit responses were 27.93%. Attitude Neutral responses did not change between pre and post visits. District B had varied responses in the categories of Algebra, Data and Probability, and Geometry, and did not change appreciably from pre to post-visit. Number Operation responses increased slightly from 23.32% to 26.86%. Measurement responses changed significantly, and decreased from 15.25% to 7.98%.

Table 33

Total Number of Responses in Each Category - Treatment Group District B

Response Category	Pre-Visit	Post-Visit
Algebra	7	2
Data & Probability	5	3
Geometry	42	38
Measurement	68	30
Number Operations	104	101
Other	42	43
Attitude Neutral	56	39
Attitude Negative	14	15
Attitude Positive	108	105

Note: The total number of responses in each category for each administration of the concept knowledge map.

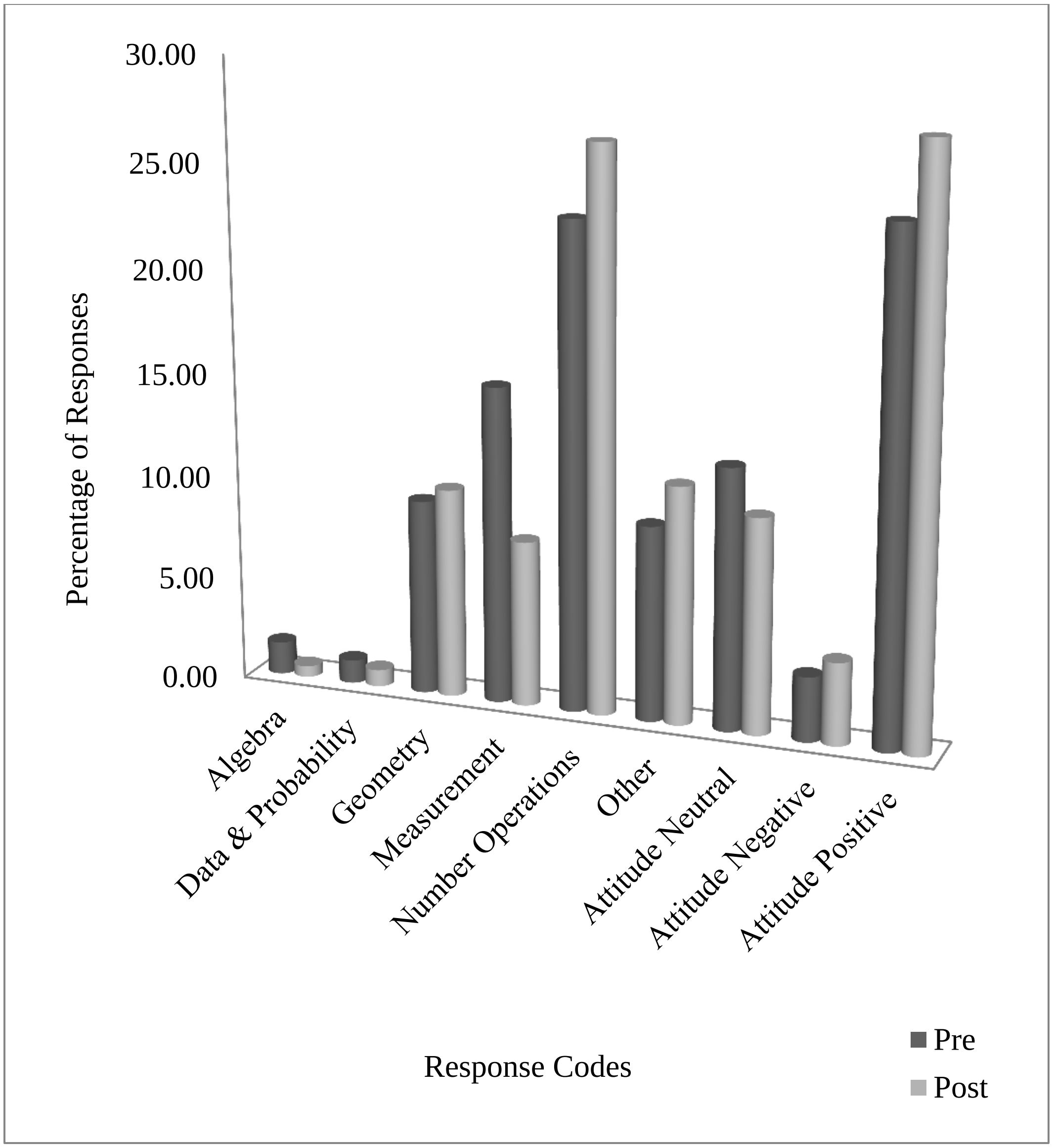


Figure 32. Student Responses Concept Knowledge Map Treatment No Control District B – All Testing Sessions

Results All Student Participants

MAS-R Results. Tables 34 and 35 show the results of the z Test for difference in means, which tests the change between repeated applications of the MAS-R, pre-visit to post-visit, and from post-visit to post-post visit. The null hypothesis states the post-test results on the MAS-R will not be less than pre-test results for the treatment group of students. The p-value from pre-visit to post-visit is .02. With an alpha level of .05, the decision was to reject the null hypothesis. The p-value from post-visit to post-post visit is .22. With an alpha level of .05, the decision was not to reject the null hypothesis. The p-value indicates the likelihood or probability of obtaining these same test values if the null hypothesis is true. With a p-value below the alpha level of .05, the statistical test results demonstrate significance; however, the practical significance of these results will be discussed in Chapter 6.

Table 34

z Test All Student Treatment Group Participants – Pre-Visit to Post-Visit

	Variable 1	*Variable 2*
Mean	2.418831169	2.188819876
Known Variance	0.78	0.63
Observations	110	115
Hypothesized Mean Difference	0	
z	2.051614973	
P(Z<=z) one-tail	0.020103548	
z Critical one-tail	1.644853627	

Note: A p-value of 0.02 < α (0.05) indicates the decision to reject the null hypothesis.

Table 35

z Test All Student Treatment Group Participants – Post-Visit to Post-Post-Visit

	Variable 1	*Variable 2*
Mean	2.188819876	2.066445183
Known Variance	0.63	0.89
Observations	115	43
Hypothesized Mean Difference	0	
z	0.756380826	
P(Z<=z) one-tail	0.22471045	
z Critical one-tail	1.644853627	

Note: A p-value of 0.22 > α (0.05) indicates the decision to not reject the null hypothesis

To test for measureable change between repeated applications of the MAS-R, the ANOVA test was performed. The null hypothesis states there will be no difference in mean scores when comparing pre-test, post-test, and post-post-test for the treatment group of students. The p-value from the ANOVA test is .04 for the treatment group of students. With an alpha level of .05, the decision was not to reject the null hypothesis. The p-value indicates the likelihood or probability of obtaining these same test values if the null hypothesis is true. With a p-value below the alpha level of .05, the statistical test results demonstrate significance; however, the practical significance of these results will be discussed in Chapter 6. Table 36 shows the ANOVA results for the treatment group of all student participants.

Table 36

ANOVA Test All Student Treatment Participants

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	110	266.07143	2.4188312	0.7919376
Column 2	115	251.71429	2.1888199	0.6302534
Column 3	43	88.857143	2.0664452	0.8912525

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	4.9651374	2	2.4825687	3.363352	0.0361032	3.0298547
Within Groups	195.60269	265	0.7381234			
Total	200.56783	267				

Note: A p-value of 0.03 > α (0.05) indicates the decision to reject the null hypothesis.

Concept Knowledge Map. Figure 33 summarizes the qualitative data for the administration of the concept knowledge map pre-visit, post-visit, and post-post-visit for all student participants. The total number of responses coded into each category for the treatment group from District A and District B appears in Table 37. Attitude Negative responses observed between pre-visit and post-visit testing decreased from 4.25% to 2.96% and increased to 7.71% at the post-post-visit. An increase in Attitude Positive was observed. Pre-visit student responses were 18.49%, 29.74% post-visit, and post-post-visit responses were 35.21%. Attitude Neutral responses fluctuated slightly between the three testing sessions. The students had varied responses in the categories of Algebra, Data and Probability, Geometry, and Measurement. Number Operations responses decreased from 30.77% to 29.45% post-visit, and to 28.53% post-post-visit. The results demonstrate a partial anticipated change in perception of mathematics as Number Operations decreased; however, the other NCTM category strands did not increase, and the positive attitude increase was also a partial anticipated change as the Attitude Negative responses did not decrease.

Table 37

Total Number of Responses in Each Category - Treatment Group Student Participants

Response Category	Pre-Visit	Post-Visit	Post-Post-Visit
Algebra	19	11	4
Data & Probability	9	5	6
Geometry	62	55	5
Measurement	98	44	11
Number Operations	268	210	111
Other	80	58	17
Attitude Neutral	137	97	68
Attitude Negative	37	21	30
Attitude Positive	161	212	137

Note: The total number of responses in each category for each administration of the concept knowledge map. District B did not complete the post-post testing. Therefore, the post-post numbers listed are from District A.

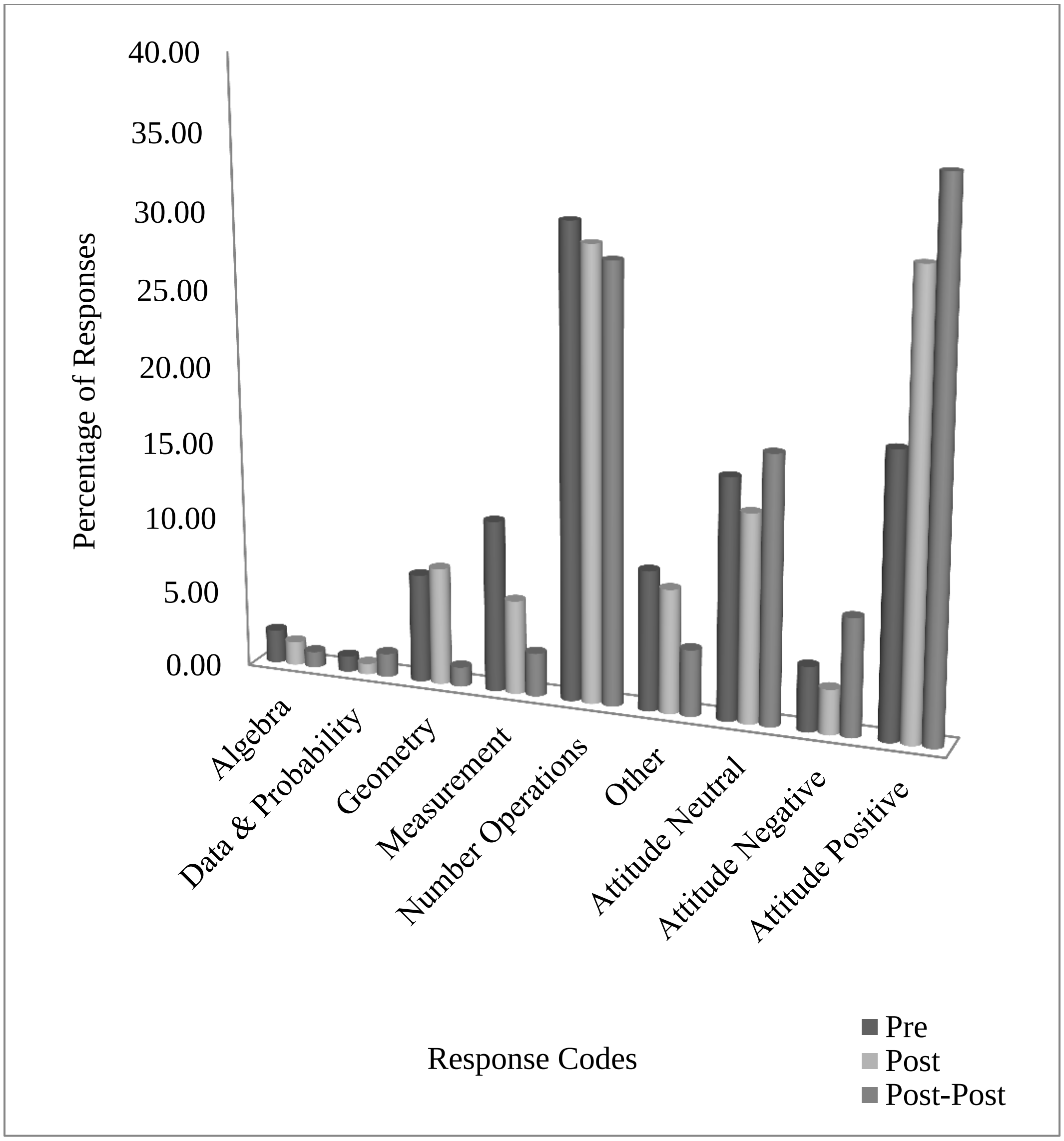


Figure 33. Student Responses Concept Knowledge Map All Treatment Groups – All Testing Sessions

Pre-Service Teachers – Matching Only Design

MAS-R Results. Table 38 shows the MAS-R means for the pre-service teacher participants. The means lessened from pre-visit to post-visit and from post-visit to post-post-visit. Table 39 lists the median of the means for the pre-service teacher participants. The median lessened from pre-visit to post-visit and from post-visit to post-post-visit;

however, the median is higher than the mean for all three visits. The mean is affected by extremely high or extremely low values, outliers, while the median is affected less by outliers and demonstrated how the anxiety levels fell into the upper half or lower half of the values. A median greater than the mean demonstrated that the pre-service teachers had higher anxiety levels.

Table 38

Summary of Mean Data – Pre-Service Teachers

Group	Pre-Visit	Post Visit	Post-Post-Visit
All Sections Treatment	3.04	2.95	2.88
Control	2.92	2.83	2.82

Note: Means were calculated for each group that participated in the study. Means were calculated by assigning point values to the responses on the MAS-R. The highest rating score possible was five and the lowest rating score was one.

Table 39

Summary of Median Data – Pre-Service Teachers

Group	Pre-Visit	Post Visit	Post-Post-Visit
All Sections Treatment	3.36	3.07	2.96
Control	2.86	2.93	2.79

Note: Means were calculated for each group that participated in the study. Means were calculated by assigning point values to the responses on the MAS-R. The highest rating score possible was five and the lowest rating score was one.

The histograms in Figure 34, Figure 35, and Figure 36 indicate the frequency and distribution of the MAS-R scores for the pre-service treatment participants. The frequency of scores demonstrated the distribution of the mean scores pre-visit, post-visit, one-week after the first visit, and post-post-visit, one-month after the first visit to the Math Center. The treatment group trend in these histograms demonstrated a left-skewed distribution of the data, which means the MAS-R levels moved toward the higher values of the frequency distribution or higher anxiety.

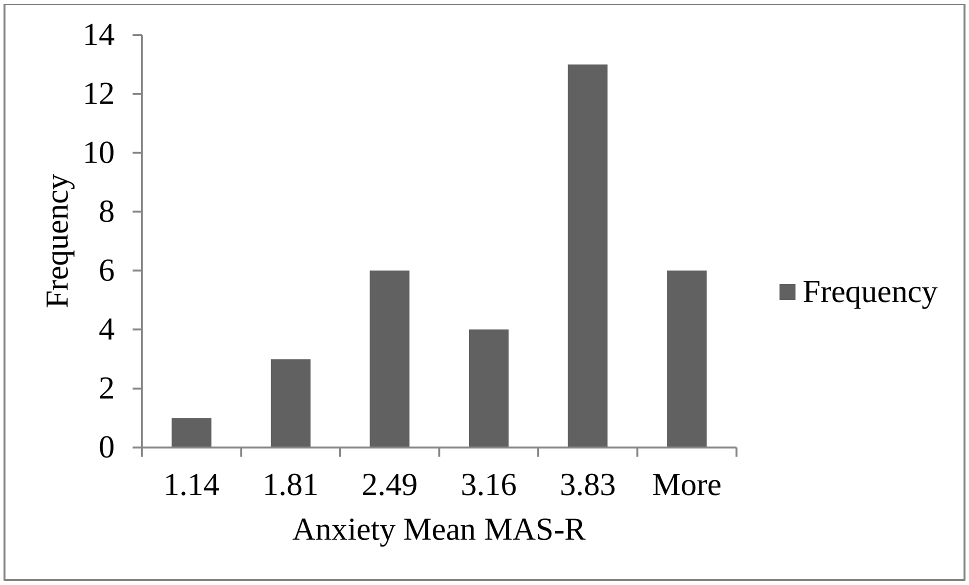


Figure 34. Histogram Pre-Service Teachers Treatment Group – Pre-Visit

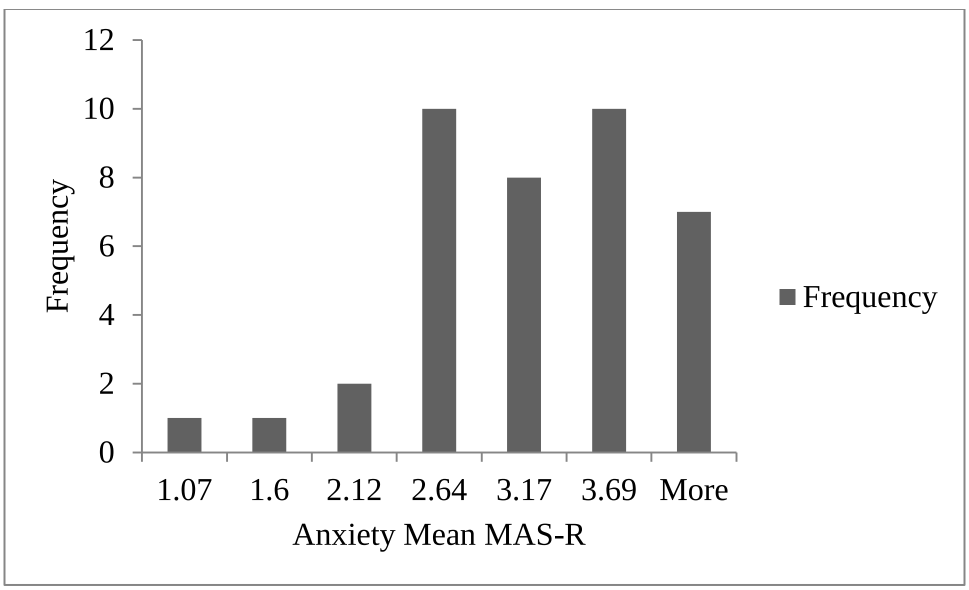


Figure 35. Histogram Pre-Service Teachers Treatment Group – Post-Visit

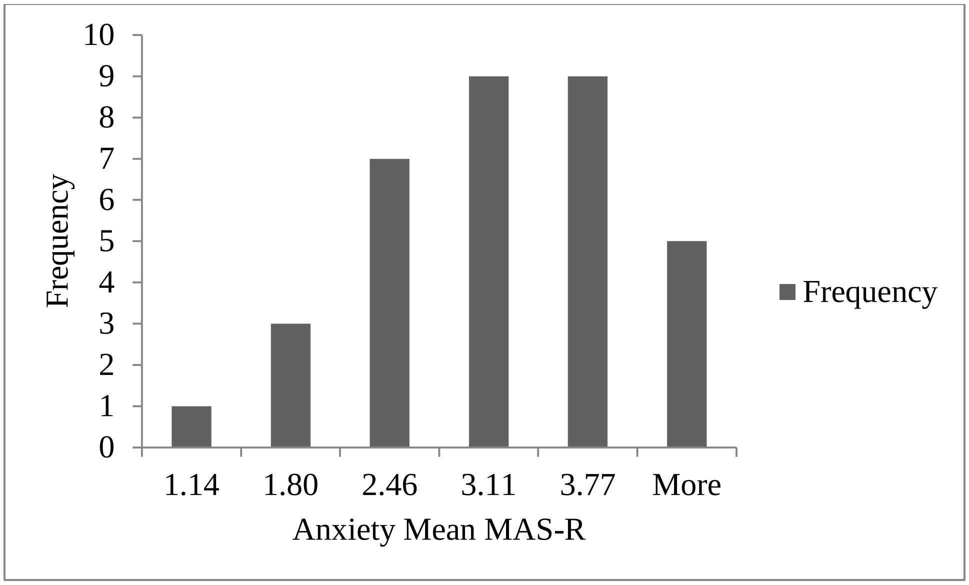


Figure 36. Histogram Pre-Service Teachers Treatment Group – Post-Post-Visit

The histograms in Figure 37, Figure 38, and Figure 39 indicated the frequency and distribution of the MAS-R scores for the pre-service teacher control group participants. The frequency of scores demonstrated the distribution of the mean scores pre-visit, post-visit, and post-post-visit. The control group trend in these histograms demonstrated a left-skewed distribution of the data, which means the MAS-R levels moved toward the higher values of the frequency distribution or higher anxiety. The trends in the histograms for both the treatment and the control group demonstrated a left-skewed distribution of data or higher anxiety levels.

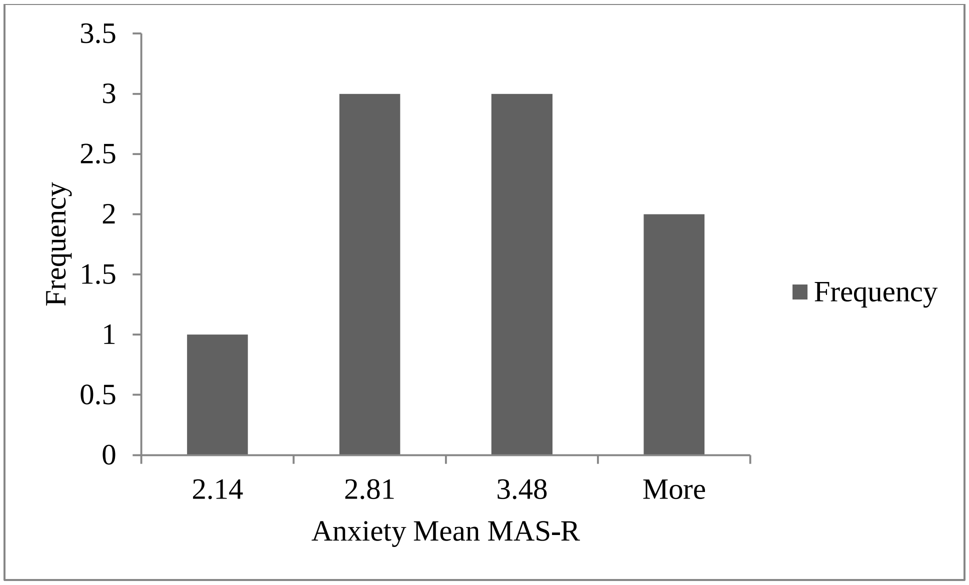


Figure 37. Histogram Pre-Service Teacher Control Group – Pre-Visit

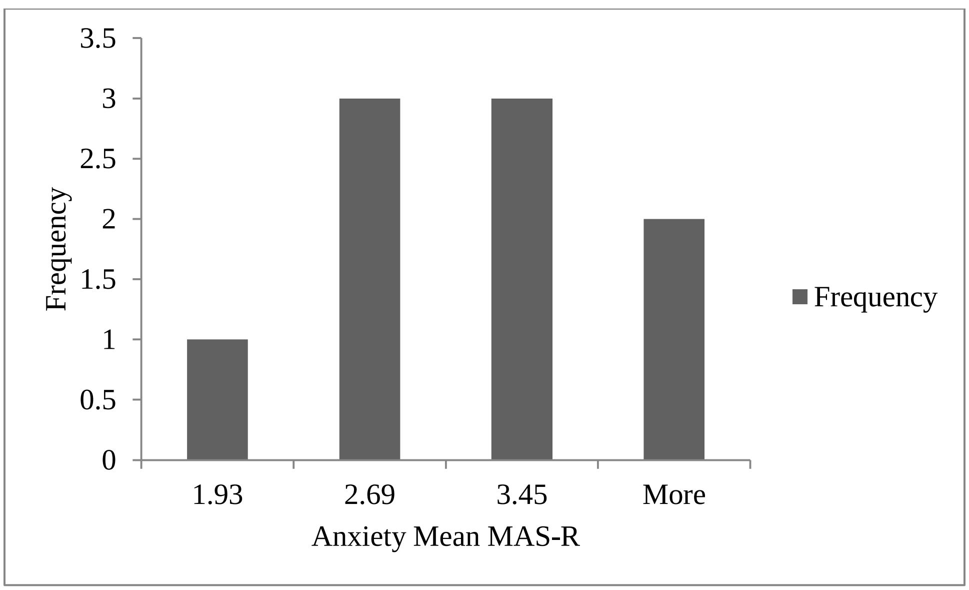


Figure 38. Histogram Pre-Service Teachers Control Group – Post-Visit

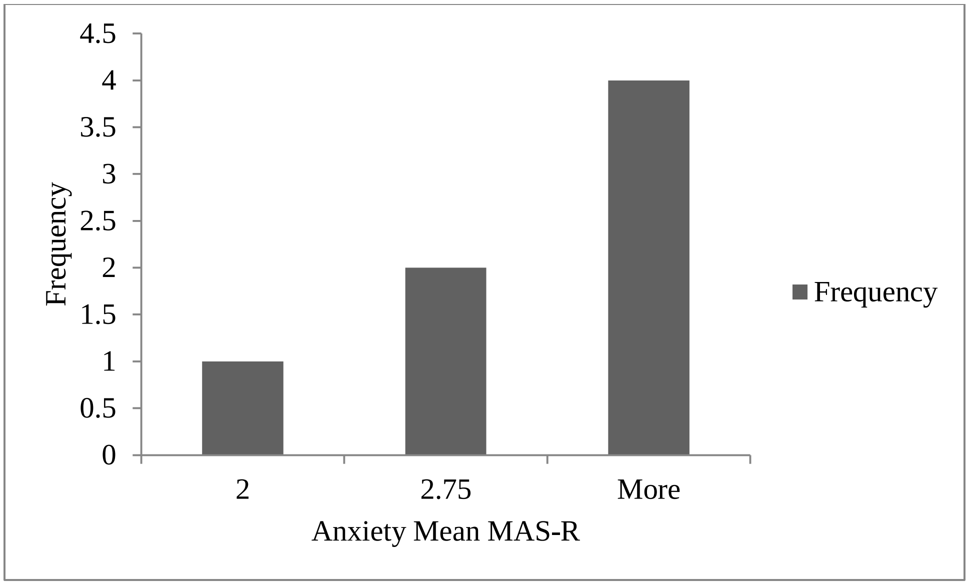


Figure 39. Histogram Pre-Service Teachers Control Group – Post-Post-Visit

To test for measureable change between repeated applications of the MAS-R, the ANOVA test was performed. The null hypothesis states there will be no difference in mean scores when comparing pre-test, post-test, and post-post-test for the treatment group of pre-service teachers. The p-value from the ANOVA test is .74 for the treatment group. With an alpha level of .05, the decision was not to reject the null hypothesis. The p-value from the ANOVA test is .91 for the control group. With an alpha level of .05, the decision was not to reject the null hypotheses. The p-value indicates the likelihood or probability of obtaining these same test values if the null hypothesis is true. Table 40 shows the ANOVA results for the treatment group, and Table 41 shows the results for the control group of pre-service teachers.

Table 40

ANOVA: Single Factor Pre-Service Teacher Treatment Group

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	33	100.28571	3.038961	0.9311514
Column 2	39	114.98352	2.9482953	0.5726373
Column 3	34	97.8	2.8764706	0.7251934

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	0.4438149	2	0.2219075	0.302781	0.7394161	3.0845768
Within Groups	75.488444	103	0.7328975			
Total	75.932259	105				

Note: A p-value of 0.73 > α (0.05) indicates the decision to not reject the null hypothesis.

Table 41

ANOVA: Single Factor Pre-Service Teacher Control Group

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	26.35714	2.928571	0.522959
Column 2	9	25.35714	2.81746	0.600907
Column 3	7	19.57143	2.795918	0.259232

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	0.085513	2	0.042757	0.089192	0.914999	3.443357
Within Groups	10.54632	22	0.479378			
Total	10.63184	24				

Note: A p-value of 0.91 > α (0.05) indicates the decision to not reject the null hypothesis.

Concept Knowledge Map Results. Figure 40 summarizes the qualitative data for the administration of the concept knowledge map pre-visit, post-visit, and post-post-visit from the pre-service teacher treatment group. The total number of responses coded into each category for the treatment group from the pre-service teachers appears in Table 42. Attitude Negative responses decreased from 7.1% pre-visit to 3.0% post-visit to 1.7% post-post-visit. An increase in Attitude Positive was observed from post-visit to post-post-visit. Attitude Neutral responses increased from 7.9% pre-visit to 9.5% post-visit to 10.5% post-post visit. The pre-service teachers had varied responses in the categories of Algebra, Data and Probability, Geometry, Measurement, and Number Operations. Number Operation responses increased from 24.0% at the pre-visit session to 31.6% at the post-visit session, and then decreased to 28.5% at the post-post-visit session.

Table 42

Total Number of Responses in Each Category - Treatment Group Pre-Service Teachers

Response Category	Pre-Visit	Post-Visit	Post-Post-Visit
Algebra	14	4	4
Data & Probability	9	4	6
Geometry	83	74	5
Measurement	117	48	19
Number Operations	163	172	131
Other	65	63	23
Attitude Neutral	61	49	124
Attitude Negative	15	16	58
Attitude Positive	115	122	254

Note: The total number of responses in each category for each administration of the concept knowledge map.

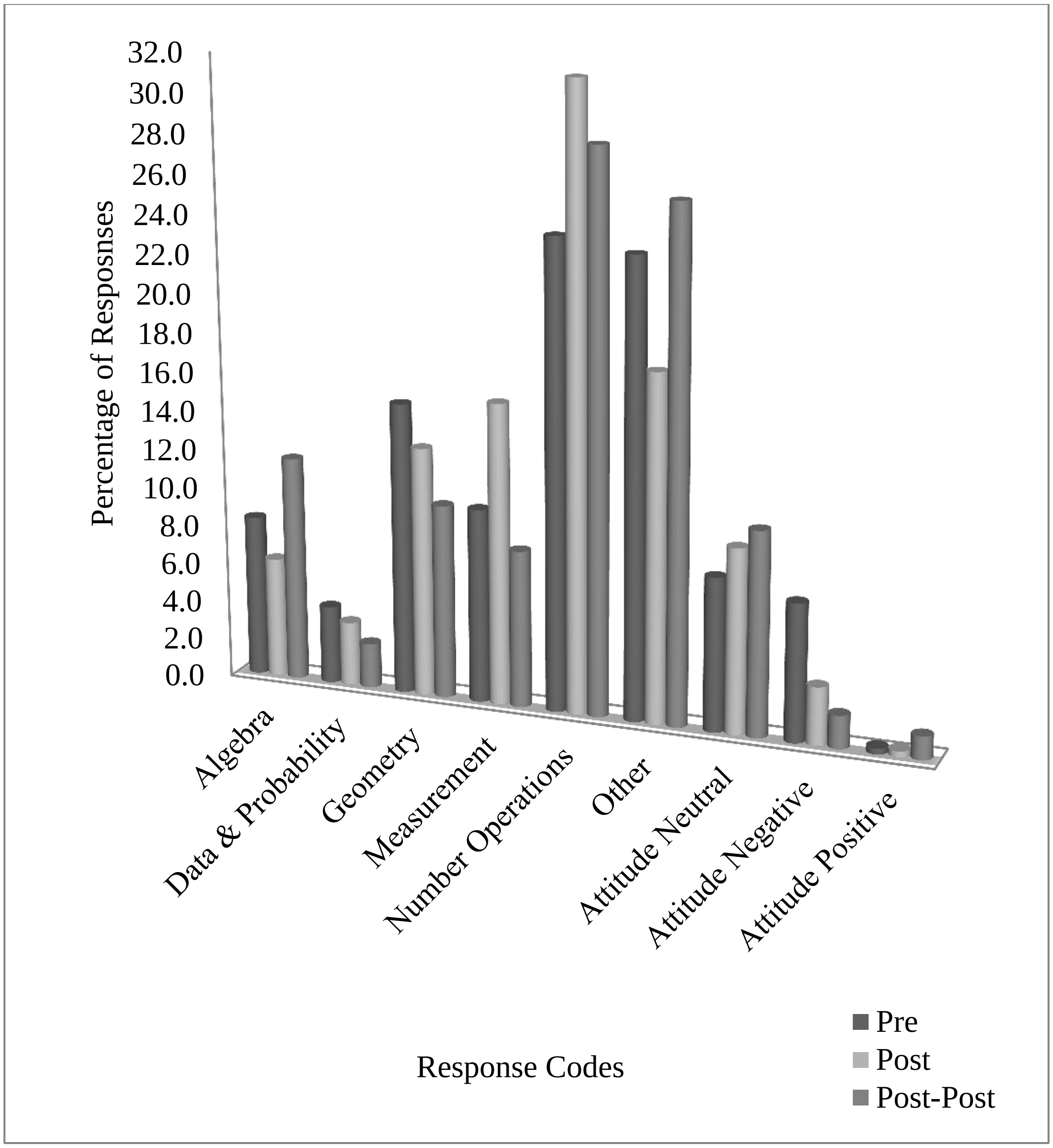


Figure 40. Pre-Service Teacher Responses Knowledge Concept Map Treatment Group – All Testing Sessions

Figure 41 summarizes the qualitative data for the administration of the concept knowledge map pre-visit, post-visit, and post-post-visit from the pre-service teacher control group. Attitude Negative and Attitude Positive responses remained steady throughout the sessions. Attitude Neutral responses decreased from 19.6% pre-visit to 6.1% post-visit and to 4.0% post-post-visit. These pre-service teachers had varied responses in the categories of Algebra, Data and Probability, Geometry, Measurement, and Number Operations. Number Operation responses increased from 29.3% at the pre-visit session to 50.0% at the post-visit session, and then decreased to 40.0% at the post-post-visit session.

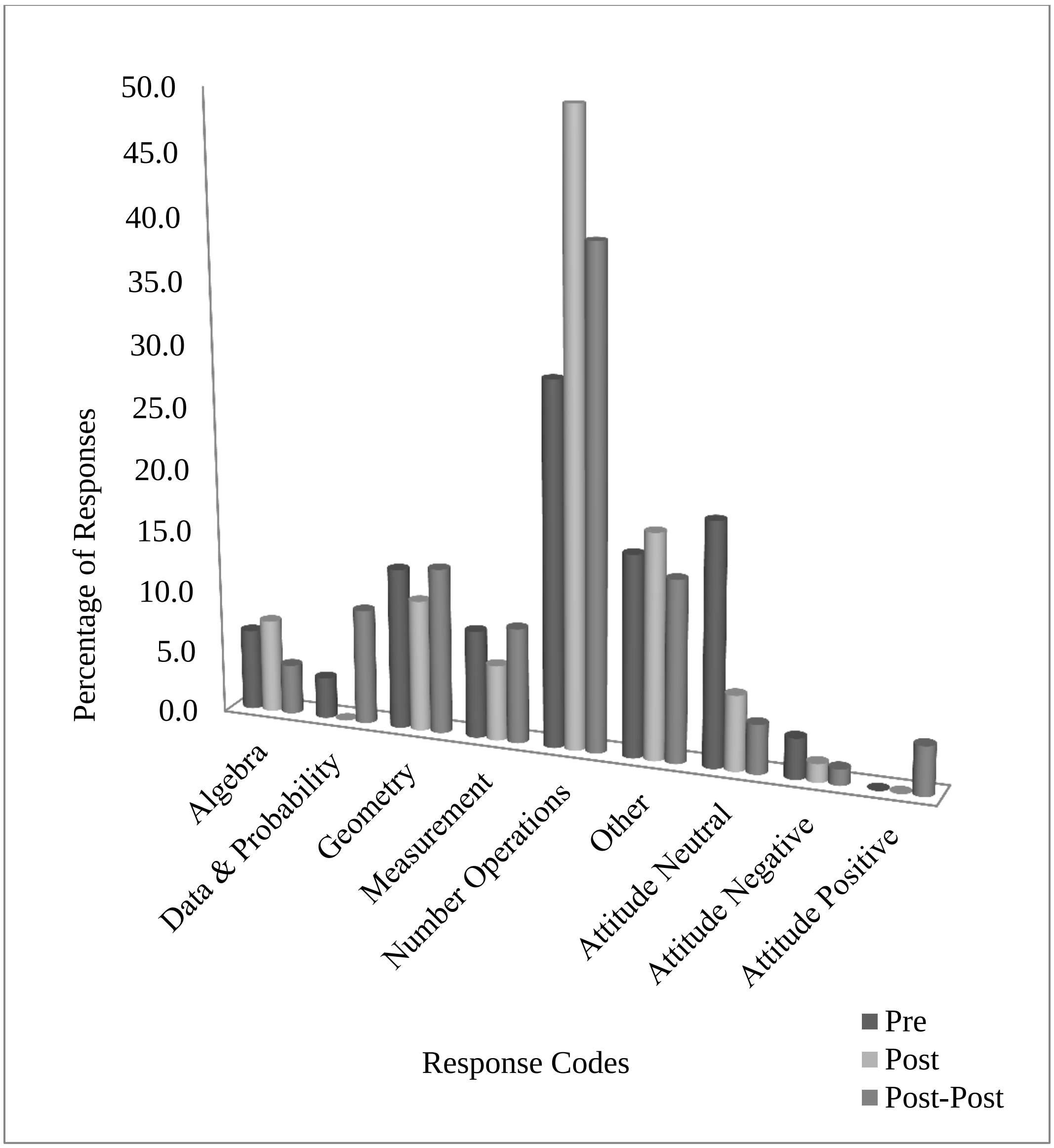


Figure 41. *Pre-Service Teacher Responses Concept Knowledge Map Control Group – All Testing Sessions*

Pre-Visit Interview of Pre-Service Teachers by the Independent Evaluator. The independent evaluator interviewed the pre-service teachers by telephone one week before they were to attend the Math Center. The pre-service teachers were students of the researcher and members of a Math Methods course. The independent evaluator reported that the pre-service teachers had mixed expectations about their visit to the Math Center. Some thought they would be helping kids with math. Another student thought, “it would be like a science fair, but math, making the activities fun but still relating them to daily life.” The independent evaluator noted that none of the students expected they would be working with a measurement assignment.

The independent evaluator asked the pre-service teachers about their attitudes, beliefs, and comfort level with mathematics. The pre-service teachers reported that math was not their favorite subject. Several of the pre-service teachers reported they suffered from math anxiety but were not afraid of math. A pre-service teacher stated that she had one good teacher, but the others did not excite her about math. Another student reported that there will be so many students to teach that she will not be able to do it well, and concluded with, “students can only be as good as their teacher.”

Observations of Independent Evaluator. The pre-service teachers were working on measurement and were given a list of activities to visit in the Math Center, which engaged them in hands-on measurement activities. The independent evaluator observed students independently and working in groups. The evaluator reported that he observed all students engaged in the exercises. Some initially experienced some frustration, but eventually engaged in the activities. He noted that the pre-service teachers would read the directions, but, “seemed to doubt if what they read was what they really needed to do! Like worrying if they were doing it RIGHT!”

The independent evaluator focused specifically on five exhibits. At the Pentominoes exhibit, the evaluator observed the students solve the puzzle “meticulously” laying out the pieces while others did not use all the pieces and experienced difficulty remembering what they had made. He reported that when the activities became difficult, some groups assisted each other while other groups asked for help from a group who had already completed the activity. At the Measure Island exhibit, the students had difficulty identifying the activity they were to complete, but he observed one group who took the time to make sure everyone in the room understood before moving on. At Measure Treasure, the evaluator observed a group in which each member of the group was responsible for a part of the answer. At Beam Me Up a Solid, the evaluator reported that the students assembled the cube, but each group came up with varying measurements from 12” to 14” depending on if the measurements included the beams or the beams and the attaching pieces. The final activity the evaluator observed was Stretch Your Knowledge, a giant-size geoboard. He stated that this activity caused frustration, and some were confused with perimeter and area. The pre-service teachers were asked to change the area of a shape and maintain the same perimeter and then change the perimeter of a shape and maintain the same area. The evaluator noted that the students commented on the broken posts on the geoboard as a reason for the difficulty they were experiencing when the students could have moved to another part of the board.

Post-Visit Interview of Pre-Service Teachers by the Independent Evaluator. The pre-service teacher participants were interviewed by phone one week after their visit to the Math Center. The evaluator asked the students about their original expectations and if the Math Center met their expectations. One student reported she thought the Math Center was a “tutoring center” and did not expect the rooms and all the activities. Another pre-service teacher reported that she expected the Math Center to not be fun and enjoyed the Math Center. All students reported the Math Center exceeded their expectations. One female student reported, “So many things to help [me] understand and help others to understand”. Another female student stated she was, “blown out of the water.”

The independent evaluator asked the pre-service teachers if the Math Center provided them with understanding toward teaching math. A female pre-service teacher responded that she had gained understanding with weather, temperature, and shapes. Another student reported that the Math Center provided explanation that he would not have thought up on his own. The pre-service teachers reported that they had gained many fun ideas to help them teach math.

The pre-service teachers were asked about their attitudes towards learning and teaching math, anxieties about learning and teaching math, and their proficiency level with mathematics. Two students reported that they were more comfortable now and feeling more positive after the visit. One pre-service teacher reported, “I am really excited to use some of what I learned”. One student reported that she did not have anxiety toward math, and she would not be teaching math, but would use what she is learning in what she will teach. One student reported he had no difficulty with math and was very good at it. Two female students said they were “better” with math now.

Focus Group Interview of Pre-Service Teachers by the Independent Evaluator. The independent evaluator begins the interview with an explanation about the purpose of the interview. The first question he posed to the pre-service teachers was, "How does the Math Center provide learning opportunities for both students and teachers?" The students' responses indicated that the math was hands-on, the manipulatives were important for student learning, and the activities and exhibits make connections to math that now make sense.

The evaluator posed the next question, "How did the experience at the Math Center affect your understanding of mathematics instruction?" The pre-service teachers' responses indicated that connections were made not only for the students, but for them as future educators as well. A female student stressed that she now feels more comfortable with math, and another student stated, "It made me realize that I needed to brush up on a few things." Another student stated, "I honestly didn't feel like it was work there."

The evaluator asked the next question, "How do you plan to use this experience in your future classroom?" Several students stated that these types of experiences were not provided to them as students, and they would be using manipulatives in their classrooms. The students suggested the use of manipulatives serve several purposes. Manipulatives will help the student learn math as it will "stick", help students make connections, and make math fun.

The next question the evaluator asked the students was, "What's the importance of the giant-size exhibits?" A male student stated that the giant exhibits provide students the opportunity to demonstrate the math to other kids. Another student suggested that a larger group of students can work as a team. A student stated that the giant-size exhibits help with attitude. The students discussed that the giant-sized exhibits take more effort, cause kids to be active learners, and the learning is associated to the movement of the body.

The evaluator asked, “How can the Math Center provide access, motivation, and inspiration for students to feel successful at mathematics?” A pre-service teacher responded that the Math Center activities provide a sense of accomplishment, and that you want to achieve and do more. A student added, “you want to do even more math and keep going”. Another suggested that the Center accommodated all learning styles. A final response suggested that kids would rather have fun and learn rather than sit there and take notes.

The final question the evaluator asked the pre-service teachers was, “How can the Math Center be improved?” The students commented that the Math Center is no longer there due to the tornado, and then they stated that more space was needed, the activities needed to be spread out more, and limit the amount of activities in one room. Several students commented that there was not enough time. The students suggested that a scavenger hunt would be fun. The evaluator asked the pre-service teachers if they think that it is important that the students who go through the Math Center make the connections to math or if they thought it was okay for the students to just enjoy it. A female student responded, “If they don’t make the connections, when they [*the students*] return to the classroom, the teacher should refer to things in the Math Center. The connection can be made in the classroom or at some point in the future.” The interview ended with a pre-service teacher statement, “I think it was a great place to go. It was a lot of fun. It was a lot of learning that students wouldn’t get elsewhere.”

In-Service Teachers

Teachers from District A participated in the Matching Only design, and teachers from District B participated in the One Control design for this study. A total of seven teachers, six treatment and one control, participated in the study; the data reported for the in-service teacher group has been combined.

MAS-R Results. Table 43 shows the MAS-R means for the in-service teacher participants. The means lessened from pre-visit to post-visit and from post-visit to post-post-visit. Table 44 lists the median of the means for the in-service teacher participants. The median lessened from pre-visit to post-visit and from post-visit to post-post-visit.

Table 43

Summary of Mean Data – In-Service Teachers Treatment Group

Group	Pre-Visit	Post Visit	Post-Post-Visit
All Teachers Treatment	2.32 (6)	1.91 (6)	1.79 (2)
Control	3.29 (1)	2.64 (1)	2.57 (1)

Note: Means were calculated for each group that participated in the study. Means were calculated by assigning point values to the responses on the MAS-R. The highest rating score possible was five and the lowest rating score was one. The numbers in the parentheses indicate the number of participants per visit.

Table 44

Summary of Median Data – In-Service Teachers Treatment Group

Group	Pre-Visit	Post Visit	Post-Post-Visit
All Teachers Treatment	2.18 (6)	2.07 (6)	1.79 (2)
Control	3.29 (1)	2.64 (1)	2.57 (1)

Note: Means were calculated for each group that participated in the study. Means were calculated by assigning point values to the responses on the MAS-R. The highest rating score possible was five and the lowest rating score was one. The numbers in the parentheses indicate the number of participants per visit.

The histograms in Figure 42, Figure 43, and Figure 44 indicated the frequency and distribution of the MAS-R scores for the in-service treatment participants. The frequency of scores demonstrated the distribution of the mean scores pre-visit, post-visit, and post-post-visit to the Math Center.

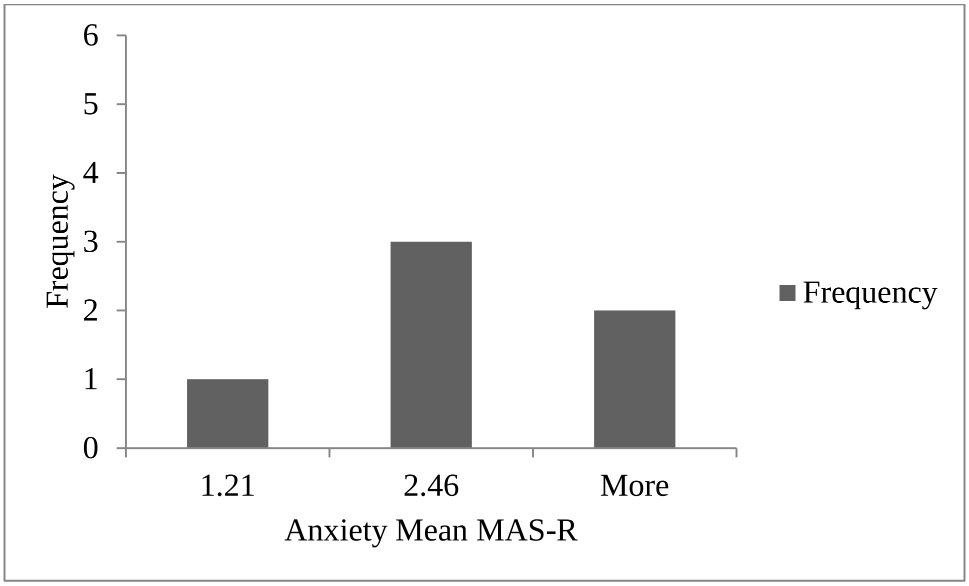


Figure 42. Histogram In-Service Teachers Treatment Group – Pre-Visit

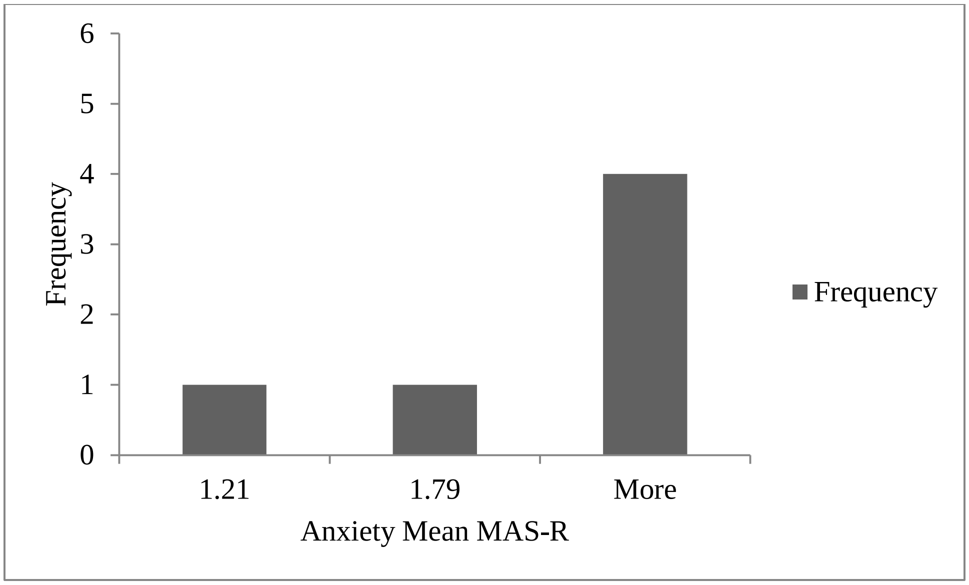


Figure 43. Histogram In-Service Teachers Treatment Group – Post-Visit

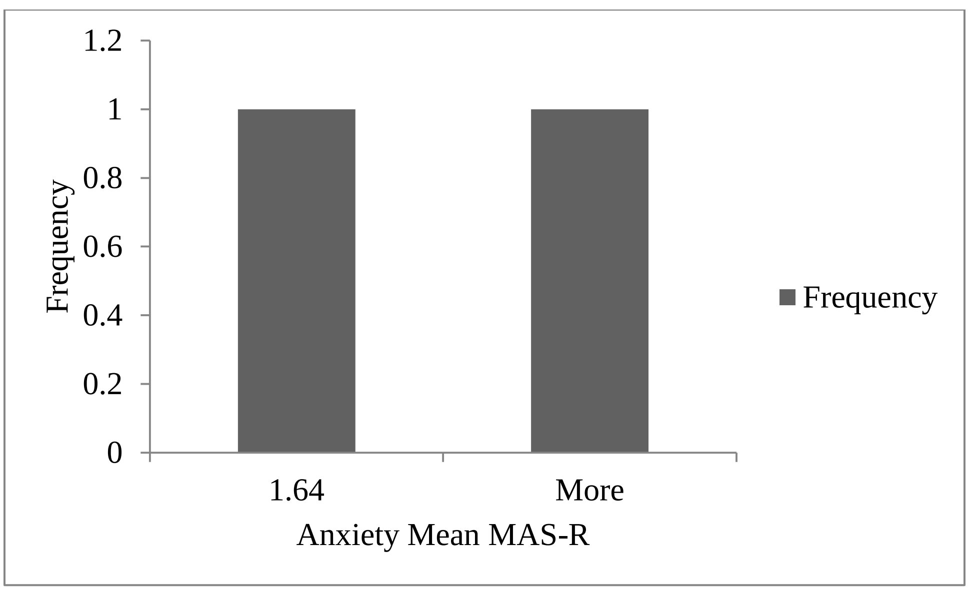


Figure 44. Histogram In-Service Teachers Treatment Group – Post-Post-Visit

The in-service teacher treatment group experienced an observable lessening in anxiety. The pre-visit administration mean for the in-service treatment group for six teachers was 2.32, the post-test administration for six teachers was 1.91, and the post-

post-administration, which was given to the two teachers from the Match-Only group, was 1.79.

Concept Knowledge Map Results. Figure 45 and Figure 46 summarizes the qualitative data for the administration of the knowledge concept map pre-visit, post-visit, and post-post-visit from the in-service teacher treatment and control groups. The total number of responses coded into each category for the treatment group from the in-service teachers appears in Table 45. Attitude Negative responses were not observed in either the treatment or control groups. Attitude Positive responses varied slightly. Attitude Neutral responses varied slightly in the treatment group and there were no responses in the control. The teachers had varied responses in the categories of Algebra, Data and Probability, Geometry, Measurement, and Number Operations in both the treatment and control groups. Number Operation responses increased from 19.5% at the pre-visit session to 29.0% at the post-visit session, and then decreased to 18.9% at the post-post-visit session.

Table 45

Total Number of Responses in Each Category - Treatment Group In-Service Teachers

Response Category	Pre-Visit	Post-Visit	Post-Post-Visit
Algebra	3	3	2
Data & Probability	1	1	0
Geometry	2	2	1
Measurement	6	5	2
Number Operations	8	9	3
Other	13	8	6
Attitude Neutral	5	2	1
Attitude Negative	0	0	0
Attitude Positive	3	1	1

Note: The total number of responses in each category for each administration of the concept knowledge map. District B did not complete the post-post testing. Therefore, the post-post numbers listed are from District A.

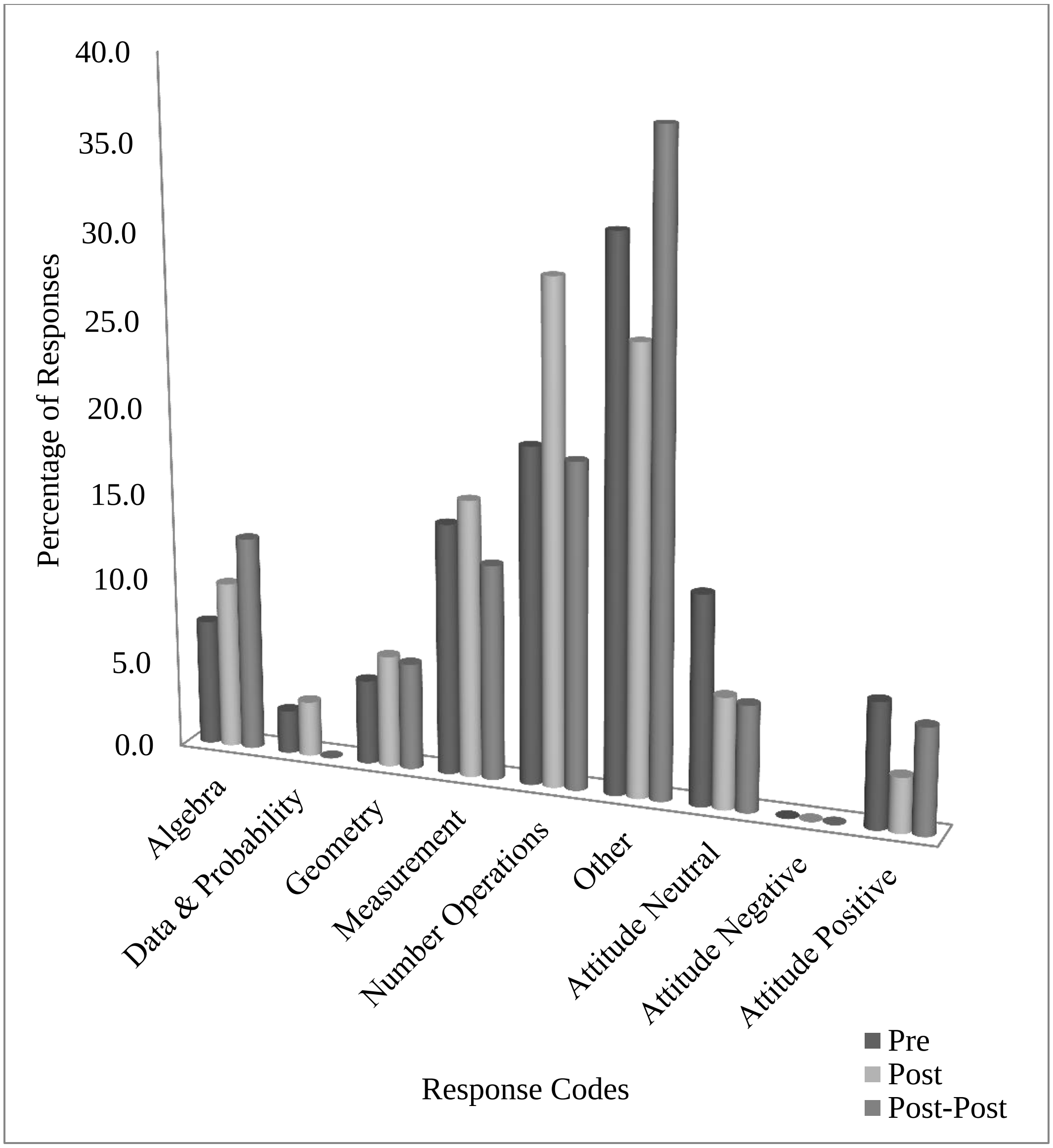


Figure 45. In-Service Teacher Responses Concept Knowledge Map Treatment Group – All Testing Sessions

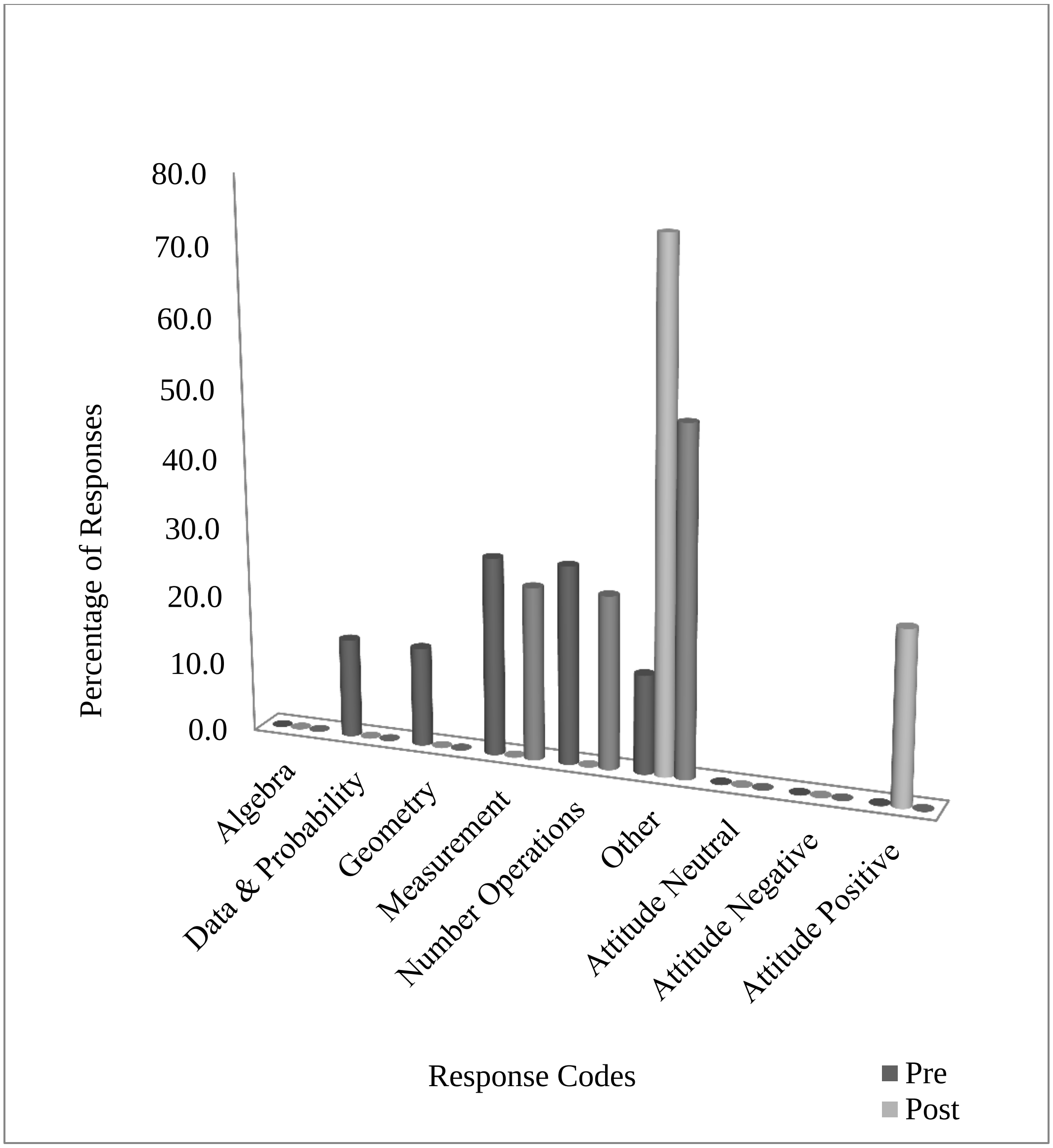


Figure 46. In-Service Teacher Responses Concept Knowledge Map Control – All Testing Sessions

Pre-Visit Interview of In-Service Teachers. The in-service teachers were interviewed in their classrooms one-week prior to the field trip visit. The teacher from School A1 is referred to as Teacher 1; the teacher from School A2 is referred to as Teacher 2; and the teacher from third grade at School B3 is referred to as Teacher 3 in this interview report. The first grade teachers were interviewed as a group and are referred to as the first grade teachers. The first question posed to the teachers was, “How did you use the organizational materials to plan the field trip experience to the Math Center?” Teacher 1 responded, “I just wasn’t too sure how to choose”, so the researcher guided the teacher to make the required selections. This teacher also added that teachers are busy, and there was much to do every day for a teacher especially with the kids. Teacher 2 expressed she hoped she had done the right thing. The first grade teachers and Teacher 3 had not made their choices at the time of the interview. However, the teachers from School 3 had previously visited the Math Center with their classes. Teacher 3 commented that the material was a little overwhelming.

The second question asked was how the teachers selected (or how they were going to select) the activities to customize the visit to the Math Center for their students. Teacher 1 responded, “Based on curriculum and what we are doing in the classroom”, and thought that being able to choose activities based on the curriculum was, “very cool.” Teacher 2 answered, “I had to pick the things that I felt were most fitting to what we taught this year or what I would like to see emphasized especially since we are visiting the day before we start MAP testing.” She added that she had chosen a couple of things as review for the MAP. The first grade teachers shared that they were reviewing the learning from this school year. Teacher 3 stated, “I am going to use the topics that my students have been studying this year and anything that I think I want to redo because we are coming right before the MAP testing so I am going to try to choose a variety of things that I think I want to redo or revisit.” The researcher asked what would she choose if they were not MAP testing. Teacher 3 responded that she would be choosing more enrichment activities and gave an example of basic fractions to extend and challenge the students.

The next question asked the teachers how they had prepared the students to visit the Math Center. Teacher 1 shared that she had told the class that the field trip was going to be hands-on learning. She added the students did not know what to expect, but told the kids that math is everywhere. The researcher asked Teacher 1 what the students' response was when they were told they were going to a "math center." The teacher reported that the students who were great at math were excited, but the ones who were not good at math were nervous.

Teacher 2 shared that she had a student who attended the Family Math Night, an evening event performed by the Math Center two months before the study, to talk to the class, but the student was not very descriptive and told the class it was fun. The researcher reminded Teacher 2 about the planning information and asked if she had seen the address for the website so that the students could take the "photo tour." The teacher did not know that was an available resource and indicated she would definitely show them the tour on the SmartBoard.

The first grade teachers had not shared with their students as spring vacation was between the time of the interview and the time of the visit. Teacher 3 remembered the photo tour but had not shown her students, and added that those conversations were going to occur after spring vacation.

The next question asked the teachers to discuss their attitudes, anxieties, and proficiency levels toward learning and teaching mathematics. Teacher 1 replied, "Well math is just very concrete you know. You either get it right or get it wrong." She continued that the class was working on geometry and that the students were instructed in groups. The "higher kids" were doing projects with angles. The next group, "we have slowed it down, and teach it a different way. They are still getting it." She reported the last group was really behind in math so it was broken down even further. The teacher explained that the kids were getting the same concept, but at their level. The researcher posed the question again, and Teacher 1 responded that she liked the math series, and explained the fifth grade was working out of the sixth grade math book because middle school complains that the kids are not ready when they get to middle school. The researcher asked how the kids were doing, and the teacher said the kids were doing quite well. The researcher asked about the math series the district used and the teacher responded, "looks like a college text book doesn't it?" She added that it intimidated the incoming fifth grade students so they take it down to a fifth grade level so the kids can understand it.

The researcher asked Teacher 1 to talk about her anxiety towards math. The teacher replied that she really loved math as a kid and high school algebra was her favorite. The researcher asked what her favorite subject was to teach, and she said that communication arts was her favorite subject. She reported loving the journey with communication arts and that the students do better in math. The researcher inquired as to why this was so, and she replied, "The math is easier because it is either right or wrong…the concrete part of it." She continued that the overlapping skills in communication arts are more difficult for students who are not on level. The researcher asked the teacher if she thought there were any ties between math and communication arts. The teacher replied that that there were as the students have to do word problems.

The researcher asked Teacher 1 about her proficiency level and she responded that she was proficient through high school math.

Teacher 2 reported that math was the subject she struggled with the most. She reported algebra was difficult and often had to draw or illustrate word problems in order to solve them. She continued that she really needed to see it. The teacher reported she enjoyed teaching math, but if teaching at a higher-grade level, would most likely not feel that way. Teacher 2 reported that her students look forward to math instruction, and that they were willing to try different things. The researcher asked her about the use of manipulatives in the classroom. The teacher reported that the class size was much bigger this year which made the use of manipulatives more difficult, but her goal was to have the kids working in pairs with manipulative as much as possible. The teacher stated her anxiety level towards math was high and that she would not do as well as she would like to do if she was given a middle school math test. Teacher 2 reported that she directs her own children to their father for help with math.

The first grade teachers expressed frustration with the school curriculum. They did not believe it was rigorous enough for the first grade. They were divided on their anxiety and proficiency levels. The teachers were asked if they thought they would pass a middle school math test. One teacher in particular reported that she would definitely not pass a middle school math test. Teacher 3 shared that she loved learning and teaching mathematics, and did not experience math anxiety. She also felt that she would pass the middle school math test, but did not use the skills required of students at an older age.

The final question asked the teachers to talk about the state of mathematics instruction in their classrooms. Teacher 1 reported that the students had made almost a five percent gain in MAP scores. The teacher reported using movement in the classroom to help the students learn math.

Teacher 2 reported that they were using a new series this year. She stated she was very excited about the new series as it had leveled centers and the series was geared toward the MAP test. She reported that the district requested that the series be implemented with fidelity to see what works and what does not work. However, she reported that since she began using it, that she did not like it as much as she had thought. The students were not able to independently use the centers, and there was no additional time for instruction. She continued discussing how the visual media did not hold the attention of the students, and she may not use it during the next school year. The researcher asked Teacher 2 if she pre-assessed her students. She reported that although she used it, she felt she was not effective in curriculum compacting for those who demonstrated mastery of the material. The kids preferred working with the whole class instead of doing something different. Teacher 2 stated that she instructs with both whole group and small group instruction. Teacher 2 concluded, “I am not a bad math teacher, but am I a great math teacher? I don’t think so…Too much out there that I don’t know if I am doing my best at it yet.”

The first grade teachers expressed concern with adhering to the program and repeatedly used the phrase, “implement the new series with fidelity” with concern about not meeting the needs of their students. Teacher 3 believed the series at the third grade level was very enriching, challenging, and liked the choice of activities. She was pleased with the structure of the series and the remediation for the students. The researcher asked if she pre-tested the class. She stated that she does not, but differentiates activities for the students by providing the students with a math menu. In addition, she utilized a "teacher's table" to work with small groups of students.

Post-Visit Interview of In-Service Teachers. The teacher participants were interviewed in their schools by the researcher one-week after the visit. The teacher from School 1 is referred to as Teacher 1; the teacher from School 2 is referred to as Teacher 2; and the teacher from third grade at School 3 is referred to as Teacher 3 in this interview report. The first grade teachers were interviewed as a group and are referred to as the first grade teachers. The teachers were first asked to talk about the comments or thoughts had their students expressed since the visit to the Math Center. Teacher 1 shared that her students had discussed their favorite activities and that none of the students had a negative comment about the field trip. Teacher 2 reported that the students went straight into MAP testing, and she had not chatted with the class. She did report, "that they all came back very positive that day" The first grade teachers reported their students were very excited and talking about how math is everywhere. Teacher 3 reported that the kids really enjoyed the visit and are finding math in other places.

The next question posed to the teachers was how they have utilized the field trip visit in mathematics instruction. Teacher 1 stated, "I just tried to bring it in and connect it to real life which it was as they experienced at the math lab." Teacher 2 reported that the students were making links, but that the day of the interview was the first day back in math instruction after MAP testing. The first grade teachers' classes made a bar graph of the room liked the best or wrote a paragraph on their favorite room. Teacher 3 had pointed out and made connections to things that the students did at the Math Center, and the students are making a PowerPoint called Where is Math?

The third question asked was, “What exhibits specifically met the objectives of math instruction in your classroom?” Teacher 1 reported that problem solving is an objective and the kids solved many problems as they made their way through the Math Center. Teacher 2 reported, “There were tons.” She talked about bowling, pattern blacks, geometric patterns, tessellations, and tangrams. Teacher 3 suggested that the exhibits met the objectives of math in different ways. She reported that the ProBots (robots) helped her to understand why students do not do well with geometric terms.

The fourth question asked the teachers if the exhibits aligned with the curriculum. All teachers reported that the exhibits and activities aligned with the curriculum. Teacher 1 stated, “I didn’t see one thing that would not align with the fifth grade curriculum.”

The next question posed to the teachers asked them to discuss the impact the giant size exhibits had on their students. The Teacher 1 responded that she felt the giant size “drew them in” Teacher 2 reported that the students loved walking up and touching them. The first grade teachers talked about how the giant size exhibits more engaging and fun for the students, and Teacher 3 stated the giant size exhibits got her students excited.

The next question asked the teachers about the impact that the parent guides had on the visit. Teacher 1 did not have parent guides. Teacher 2 reported that she was not sure that she had enough parents, but was pleased with the way the parents were guiding the students. The first grade teachers shared that their parent guides were “fabulous.” They helped the children build understanding and get engaged with the activities. The first grade teachers had taken the advice from Teacher 3 who visited the Math Center the day before to keep the parents in one room to become experts in assisting the students.

Teacher 3 reported that other than trying to keep the kids focused only one parent who sat down and played games with the kids had an impact. Some parents were good friends and talked while other parents did not spread out but played at one game together.

The teachers were asked about the changes in attitudes, anxiety, or proficiency levels in themselves or in their students since the visit to the Math Center. Teacher 1 stated, “The ones who were great with math anyway, still enjoy math. After the visit, some of my lower ones are at least trying to put forth effort.” Teacher 2 mentioned (and chuckled) that there were a whole bunch of students who finished the MAP way faster so maybe many of them gained confidence. The first grade teachers all believed their students did not experience anxiety at the first grade level and the students are very enthusiastic about math. Teacher 3 could not comment on the students’ proficiency levels but noticed a change in how excited they were and that the students now see that math is all around them.

The final question asked the teachers to discuss changes that have occurred in math instruction since the visit to the Math Center. Teacher 1 reported:

> The test is coming up, it is still rigor, rigor, rigor with math, and I am going to be honest so I don’t see much change in instruction because I know where I am going so I cannot deviate really, but we are doing a lot of hands-on, but we were doing that prior to coming to the Math Center.

Teacher 2 mentioned she is talking to the students about how math applies to every day. The first grade teachers reported that there had been no changes, but the visit validated the hands-on learning they do in the classroom to get the kids engaged. Teacher 3 was trying to connect games and activities to the games and activities in the Math Center.

Focus Group Interview of In-Service Teachers. In attendance at the focus group interview was the researcher, the independent evaluator, the teacher from School 2, who will be referred to as Teacher 2 during this interview report, and the third grade teacher from School 3, who will be referred to as Teacher 3 during this interview report. The independent evaluator began the interview by asking the teachers if they thought the students were making connections to math and how they looked at learning in the Math Center. Teacher 3 said, "I think it depends on the age, but I do think whether you realize it or not they are learning knowledge that will help with math concepts along the way." She continued that having conversations with students and making connections is important. Teacher 2 was impressed that her students seemed to see the math while at the Math Center, but they did not see that this is like the math we do at school.

The conversation drifted to how well the students followed the directions and Teacher 2 stated that the adult guides are important to encourage the students and guide them to try things the students may not necessarily be willing to try.

The researcher asked how the Math Center provided learning opportunities for both students and teachers. Teacher 3 shared that the teachers in her group wanted to takes pictures and use the ideas in class. Teacher 2 felt the testing following the visit caused her to skip over things and had shared that maybe this would have not happened had she visited earlier in the school year.

The teachers were asked about how the visit affected their mathematics instruction and its effects based on the fact that both teachers' visits were followed by MAP testing. Teacher 3 stated she had tried to add more center-type activities in her instruction.

The teachers moved the topic of discussion to the time spent in each room and the researcher inquired if the teachers would like the visit to be a free selection format. Teacher 3 said she would love to have more time in a room, but she needed to have the structure as she was not sure how the students would handle a free selection format. Teacher 2 added that the 25-minute rotations caused the students to immediately begin because they knew they had limited time. She continued to say that if she was going to get the most for her students she would visit twice during the year. Once early at the beginning of the school year with 25-minute sessions and then again in the spring with a more open feel when the students could explore their interests and talents.

The researcher asked the importance of the giant size exhibits. Both teachers responded that it was very important and the giant size exhibits attracted the students' attention right away. Teacher 3 stated that her students only wanted to use the large Chess set and not the smaller sets. The researcher asked the teachers if they felt there was a point that pieces get too big. Teacher 3 suggests that large is good but too large would stop the kids from seeing and participating in the movement of the pieces. She suggested that we keep the tangrams, "I wouldn't make those any bigger. Like they are trying to see how they go together. They love those. They come back to the room and they say those are big. That is huge. Don't lose that okay?"

The researcher asked how the Math Center provides access, motivation, and inspiration for students to feel successful at mathematics. Teacher 2 replied, "It is definitely motivating. They are feeling successful." Teacher 3 added, "They feel success at whatever they are doing…I think my kids walked away with, 'I did really good with math."

A conversation about the directions ensued, and Teacher 2 suggested that a Math Center facilitator give a brief explanation each time students switched to a different room. The researcher suggested using pictures instead of words, and Teacher 3 thought that written directions were needed, but less information. Teacher 2 said that it depended on the balance between exploration and gaining knowledge. She continued that her students liked seeing the word symmetry because they had studied symmetry. Both teachers agreed that a hint was needed in the form of a vocabulary word to help the students make the connections and use the word as they were interacting with the exhibits.

The researcher asked the teachers for their suggestions for improvements. Both teachers felt that the cash register activity needed revision, as they did not believe the kids were making change and taking away the needed skills for third grade. Teacher 2 wished the kids could go more than once during the year, but was not sure how it would work financially. The researcher stated that there were plans in the works to address multiple visits in one school year.

The interview ended with a discussion about the devastation from the tornado and the hopes and plans to rebuild the Math Center.

Study Data Compilation

MAS-R. The histograms in Figure 47, Figure 48, and Figure 49 indicated the frequency and distribution of the MAS-R scores for all treatment participants. The frequency of scores demonstrated the distribution of the mean scores pre-visit, post-visit, and post-post-visit to the Math Center, and show a lessening of anxiety levels.

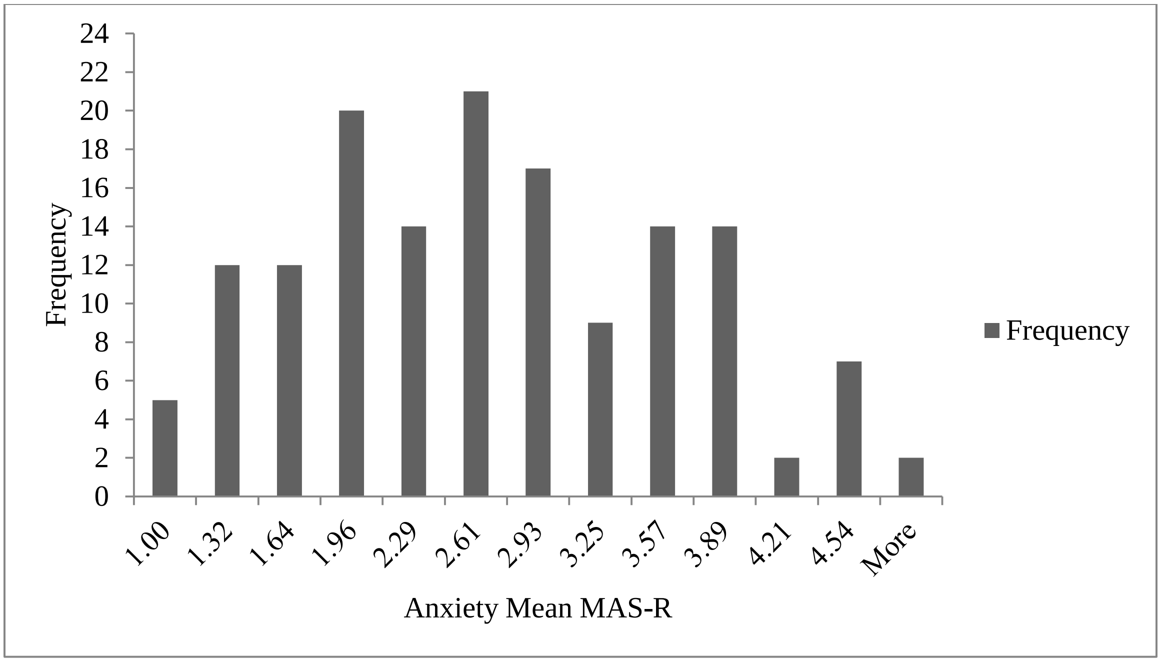


Figure 47. Histogram All Treatment Groups – Pre-Visit

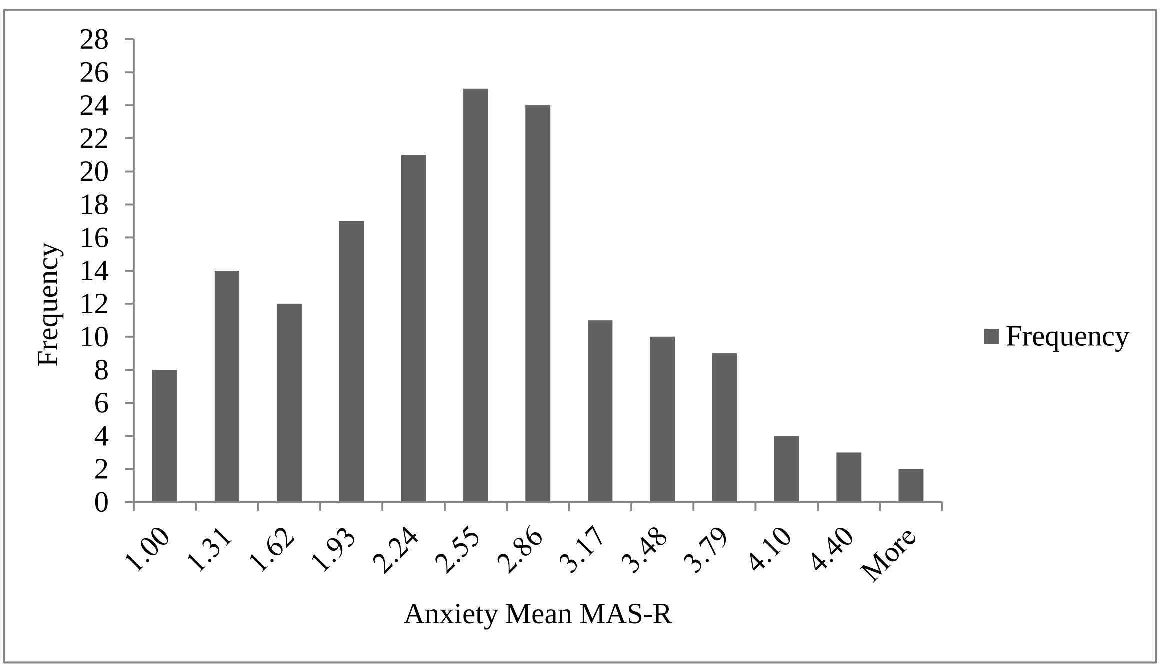


Figure 48. Histogram All Treatment Groups – Post-Visit

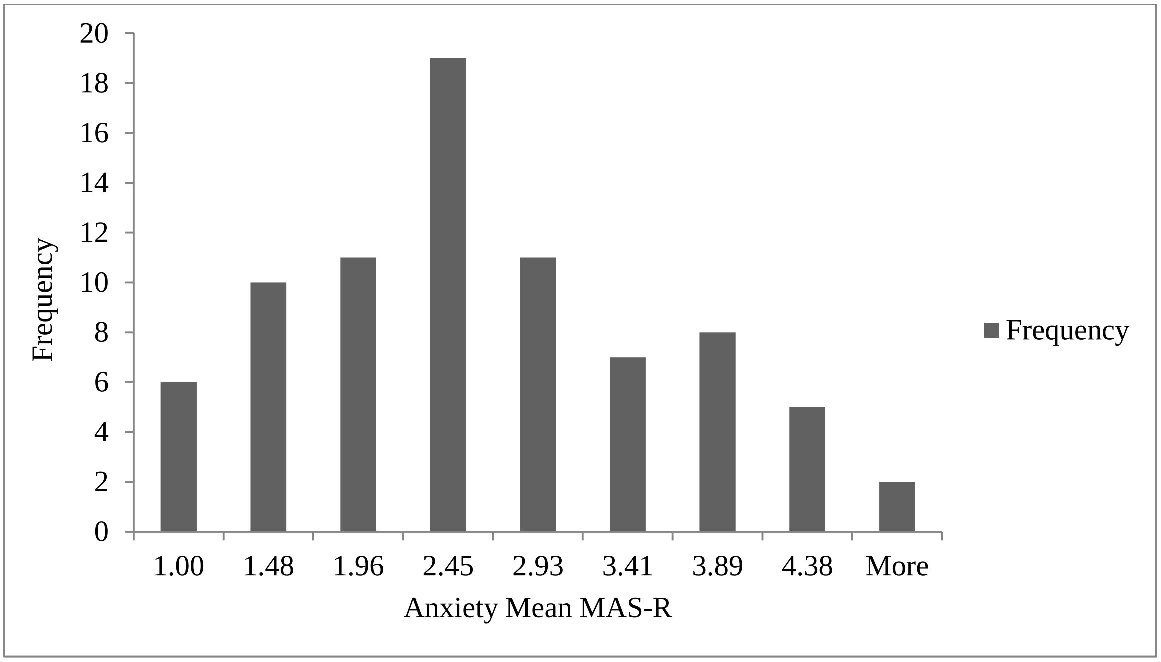


Figure 49. Histogram All Treatment Groups – Post-Post-Visit

Tables 46 and 47 show the results of the z Test for difference in means, which tests the change between repeated applications of the MAS-R, pre-visit to post-visit, and from post-visit to post-post-visit. The null hypothesis states the post-test results on the MAS-R will not be less than pre-test results for the treatment group of students. The p-value from pre-visit to post-visit is .03. With an alpha level of .05, the decision was to reject the null hypothesis. The p-value from post-visit to post-post visit is .37. With an alpha level of .05, the decision was not to reject the null hypothesis.

Table 46

z Test All Treatment Participants – Pre-Visit to Post-Visit

	Variable 1	*Variable 2*
Mean	2.552253116	2.363736264
Known Variance	0.88	0.71
Observations	149	160
Hypothesized Mean Difference	0	
z	1.853598097	
P(Z<=z) one-tail	0.03189834	
z Critical one-tail	1.644853627	

Note: A p-value of 0.03 > α (0.05) indicates the decision to reject the null hypothesis.

Table 47

z Test All Treatment Participants – Post-Visit to Post-Post-Visit

	Variable 1	*Variable 2*
Mean	2.363736264	2.4079566
Known Variance	0.71	0.96
Observations	160	79
Hypothesized Mean Difference	0	
z	-0.34332602	
P(Z<=z) one-tail	0.365676603	
z Critical one-tail	1.644853627	

Note: A p-value of 0.36 > α (0.05) indicates the decision to not reject the null hypothesis.

Concept Knowledge Maps. Figure 50 summarizes the qualitative data for the administration of the concept knowledge map pre-visit, post-visit, and post-post-visit responses of the treatment participants. The total number of responses coded into each category for the treatment group from all participants appears in Table 48. Attitude Positive responses increased from pre-visit to post-visit and from post-visit to post-post-visit. Attitude Negative responses decreased from pre-visit to post-visit and increased from post-visit to post-post-visit. Algebra and Data and Probability did not vary significantly during the study. Geometry and Measurement responses were steady from pre-visit to post-visit but decreased significantly from post-visit to post-post-visit. Number Operation responses increased from pre-visit to post-visit and decreased post-visit to post-post-visit to levels below the pre-visit responses.

Table 48

Total Number of Responses in Each Category - Treatment Group All Participants

Response Category	Pre-Visit	Post-Visit	Post-Post-Visit
Algebra	36	18	10
Data & Probability	19	10	12
Geometry	147	131	11
Measurement	221	97	32
Number Operations	439	391	245
Other	158	129	46
Attitude Neutral	203	148	193
Attitude Negative	52	37	88
Attitude Positive	279	335	392

Note: The total number of responses in each category for each administration of the concept knowledge map. District B did not complete the post-post testing. Therefore, the post-post numbers listed are from the students and in-service teachers from District A and the pre-service teachers.

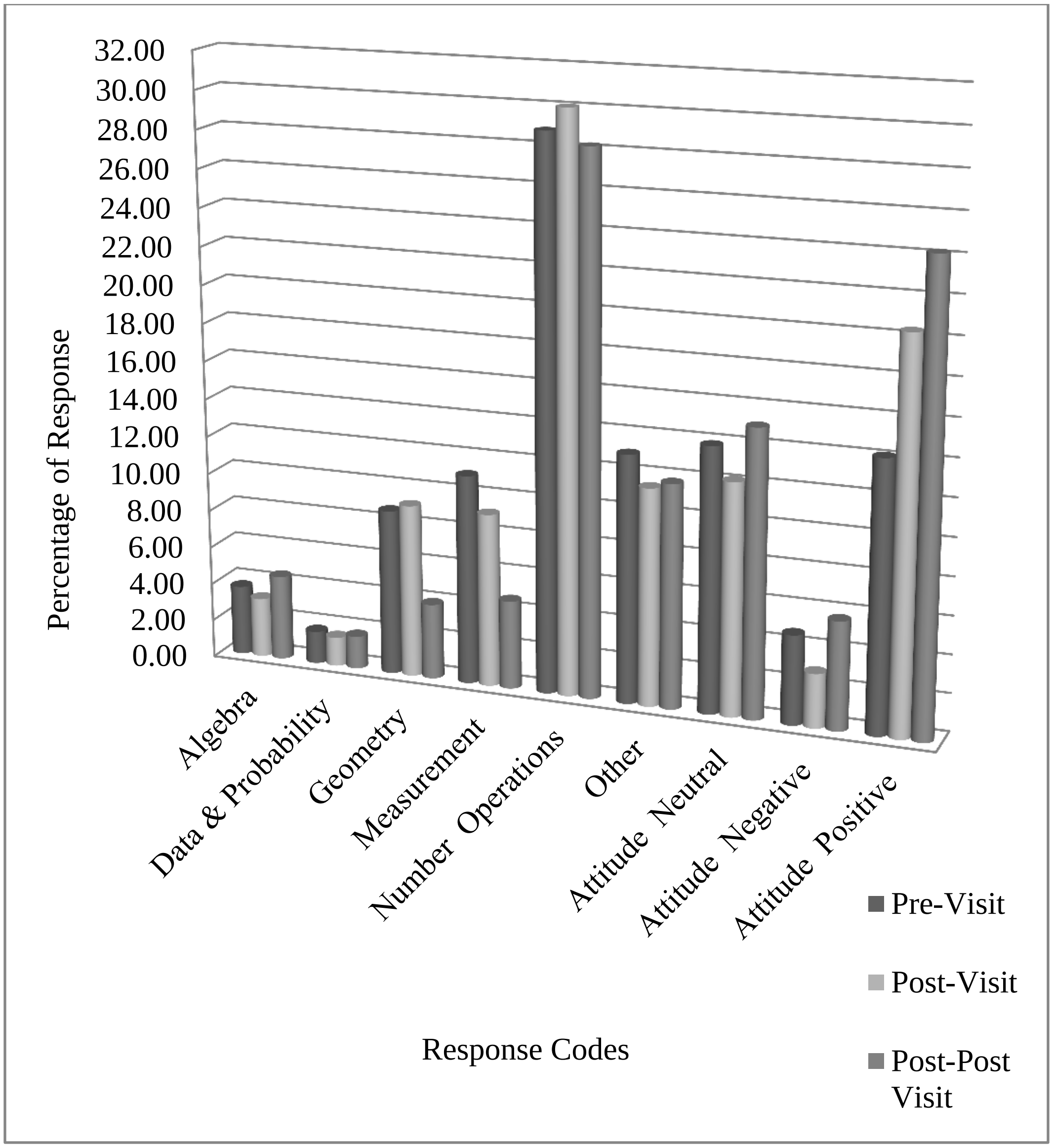


Figure 50. All Treatment Participant Responses Concept Knowledge Map – All Testing Sessions

Summary

Chapter 5 presented the results of a two-hour field trip to a Math Center located in a major metropolitan area of a Midwestern city, which was designed to improve attitudes towards mathematics and improve mathematical understanding. Anxiety inventories, knowledge concept maps, interviews, and observations were implemented to examine the effectiveness of the visit to lessen math anxiety and improve attitudes toward mathematics. Elementary students, their teachers, and pre-service teachers from a local university provided the data to analyze the visit to the Math Center. Quantitative data were analyzed from the MAS-R test for anxiety from each group of participants and reported for each visit pre to post-visit and post-visit to post-post-visit for the match only participants and pre-visit to post-visit for the one-control participants. The results from analysis of each individual field trip experience indicated the decision to not reject the null hypotheses. All post to post-post-visits indicated the decision to not reject the null hypotheses.

Analyzing the data by each group of participants and combining all participants returned different results. The treatment group of student participants demonstrated a lessening in anxiety. The test values from the MAS-R analyzed for the student participants indicated the decision to reject the null hypotheses on the z Test and ANOVA tests. The pre-service teacher participants experienced the highest levels of anxiety pre, post, and post-post-visit. Although their anxiety lessened, the ANOVA test values indicated the decision not to reject the null hypothesis. The in-service teachers demonstrated an observable lessening of anxiety. The test values for all participants demonstrated the decision to reject the null hypotheses.

The qualitative data were analyzed from the concept knowledge maps and the responses were coded by the NCTM strands of mathematics or by attitudes, negative, neutral, or positive. The combined data from all participants demonstrated an increase in Attitude Positive responses. Themes from the interviews emerged as well as observations by the independent evaluator will be discussed in Chapter 6.

Chapter 6 discusses the results obtained from the study. Suggestions are presented for future research and the researcher will present an explanation based on results of this study, which discusses why student achievement is slow to show improvement. Recommendations to improve mathematics education and a model of bridging the fields of informal and formal mathematics education will be addressed.

Chapter Six: Drawing Conclusions, Making Connections, and Crossing the Bridge

Student achievement in mathematics in the United States has not met national goals and expectations and continues to lag behind other nations in the world. Efforts to improve student achievement in mathematics have focused on developing effective teachers and teaching practices, creating state and national standards, and raising test scores. Advances in neuroscience have not been absorbed into the mainstream of educational practices, and societal acceptance about being “bad at math” remains the norm. This study investigated a Math Center designed to bridge the “Body of Knowledge,” formal educational practices with the “Body of Experiences,” informal educational practices to change the prevailing negative attitudes toward math, decrease math anxiety, and build mathematical understanding for students to “cross into a new understanding of mathematics.”

This chapter contains the themes, results, conclusions, and recommendations for future research from this study. The purpose of this study was to investigate the effect(s) of a two-hour field trip to the Math Center on elementary students, their teachers, and pre-service teachers. Data were collected from study participants in order to triangulate the results. In order to measure the change in anxiety level, the MAS-R, a Likert scale instrument, was utilized pre-visit, post-visit, and post-post-visit. To evaluate changes in understanding, a knowledge concept map that asked, “What is math?” was employed pre-visit, post-visit, and post-post-visit. To examine the quality of the visit, an independent evaluator observed the participants during the field trip visit, and interviews conducted by the independent evaluator and/or researcher were utilized to evaluate the quality and effects of the visit through the perspective of the pre-service and in-service teachers.

The purpose of the Math Center is to develop positive attitudes toward mathematics and demonstrate how math works by providing positive experiences for children to connect mathematical instruction in the classroom to their schemata using their hands and minds. This study sought to determine if the Math Center delivers its mission, and if it does, the level of excellence in the quality of the experiences it delivers. What changes did elementary students, their teachers, and pre-service teachers from a local university experience from a visit to the Math Center, and did they lead to lowering math anxiety, improving attitudes towards mathematics, and/or an increase in mathematical understanding?

The Bridge Deck (Math Center) and the Concrete (Results) that Hold It All Together

A summarization of student, pre-service teacher, and in-service teacher results follow. Connections to research and recommendations for further research are interwoven as the results are triangulated.

Student Results. The student participants for the study were composed of first, third, and fifth grade elementary students. The students' levels of anxiety significantly lessened from pre-visit to post-visit experiences. The average level of anxiety of the students was 2.41 before visiting the Math Center, and lowered to 2.19 after visiting the Math Center. Geist (2010), Tocci and Englehard (1991), and Wahl's (2005) studies concluded that negative attitudes and math anxiety begin in the primary years, and this study supported their findings.

Reporting the results in increments for the student participants first by each teacher and/or class, then by each district, and finally aggregated as a total of all participants permitted a detailed examination and holistic investigation of the effectiveness of the Math Center. The descriptive statistics reported by class did not indicate a significant lessening of anxiety; however, an observable lessening of anxiety was noted. The holistic aggregate reporting of the descriptive statistics for all the student treatment participants indicated a significant lessening of anxiety. This caused the researcher to assess whether the decreases in the anxiety levels in the students were meaningful and demonstrated practical significance. Overall anxiety levels decreased approximately 10%. The decrease from one visit combined with anxiety levels being sustained through the post-post testing indicated the visit was worthwhile and positively affected the student participant. However, further study on the frequency of visits over a school year and a longitudinal study over several years would yield worthwhile information for the Math Center, the instruction of mathematics, and formal education.

It is interesting that several students reported an anxiety level of a 1.00, which is the lowest possible rating for anxiety; however, there were no student participants who reported an anxiety level of 5.00, which would be the highest possible rating. In addition, there were no 1.00 ratings in any other grade level or group of participants except for the first grade. A control group would have yielded insight into this occurrence, and further studies on instruments to measure anxiety in primary students would be of benefit.

The students' Attitude Negative responses on the concept knowledge map decreased from 4.25% pre-visit to 2.95% post-visit and their Attitude Positive responses increased from 18.49% pre-visit to 29.74% post-visit. Hardiman (2010), Hinton et al., (2008), Jensen (2005), Sousa (2008), Tokahuma-Espinosa (2011), and Willis (2010) research stated that the brain learns best when presented with positive experiences. The student results suggested that the Math Center provided positive learning experiences.

Although Number Operation responses slightly decreased from pre-visit to post-visit, nearly one-third of all student responses on the concept knowledge map focused their answers to the question, “What is math?” as adding, subtracting, multiplying, and dividing. In order to conclude an increase in mathematical conceptual understanding, an increase in responses for Algebra, Data and Probability, Geometry, and Measurement needed to have shown a significant increase. This was not the case. Although, it is most probable that one visit was not enough experience with mathematics to have shown an increase in conceptual understanding, additional research on the effects on conceptual understanding needs to be conducted, and further research needs conducted on the amount of time in the classroom dedicated to the learning of mathematical operations. The design for this research should include the effects on students over the course of a school year as well as the effects of several field trip visits on teachers, instruction, and students over the course of the school year.

The first grade students responded with higher Attitude Positive responses on the concept knowledge map; however, the average level of the MAS-R was not lower for the first grade students. These results could have occurred because the MAS-R had a Flesch-Kincaid reading level of 2.3 and/or because the MAS-R had some double negative statements. As stated earlier, these results support research that anxiety begins in the primary years. However, examining the results across the three grade levels that participated in the study indicated that positive attitudes toward math are higher in first grade than in the third and fifth grades. In fact, the Attitude Positive responses pre-visit averaged for the third and fifth grades were 9.43% while the first grade Attitude Positive responses averaged 43.17%. This decrease in positive responses implies that positive attitudes toward mathematics decrease as grade level increases. Wahl's (2005) research supports these findings.

The lessening of anxiety, the decrease in Attitude Negative responses, and the increase in Attitude Positive responses demonstrate that the visit to the Math Center benefited the students. The post-visit to post-post-visit anxiety levels indicated that the anxiety levels did not significantly change. This supported the research of Falk and Dierking (2002) and Farmer et al. (2007), which indicated that an improvement in attitudes is retained for at least a year after a field trip visit.

Another area to research is how the field trip visit affected the students' classroom teacher's mathematics instruction. The teacher is the most effective factor in the classroom. Further research needs conducted to investigate how the effects from the field trip visit on the teacher affected the students.

Pre-Service Teacher Results. The anxiety levels of the pre-service teachers lessened from 3.04 pre-visit to 2.95 post-visit to 2.88 post-post-visit; however, these differences were not significant. The Attitude Positive responses of the pre-service teachers did not change between the pre-visit and post-visit testing and the one percent increase from post-visit to post-post-visit testing is not significant. The Attitude Negative responses decreased 4.1% from pre-visit to post-visit testing, and decreased another 1.4% from post-visit to post-post-visit testing. In fact, the pre-service teacher participants experienced the highest levels of math anxiety and the poorest attitudes towards mathematics of the participants in this study. These results supported the research of Ashcraft and Kirk (2001), Geist (2010), Miller and Mitchell (1994), and Tocci and

Englehard (1991) whose research concluded that attitudes in math directly influence success in mathematics. These students represent the 67-75% of students who leave high school with some form of math anxiety. They are the product of more than 12 years of math instruction.

Most interesting to the researcher was a female student, whose MAS-R anxiety levels were 4.43 pre-visit, 4.21 post-visit, and 4.43 post-post-visit with the highest possible score being a 5.0. Her responses on the concept knowledge map were similar to the MAS-R inventory in the fact that they increased from pre-visit to post-visit, but then decreased from post-visit to post-post-visit. On the pre-visit concept knowledge map, of the 11 responses, seven were Number Operations, one was Geometry, one was Algebra, and two were Other. On the post-visit concept knowledge map, of the 18 responses, three were Number Operations, four were Geometry, 10 were Measurement, and one was Attitude Neutral (balancing/real life). On the post-post concept knowledge map, of the six responses, one was Number Operations, three were Measurement, one was Algebra, and one was Geometry.

During the pre-visit interview, this pre-service teacher indicated that she expected the visit not to be fun. At the post-visit interview, she indicated she had gained understanding and many ideas to teach math and was quoted as being, “blown out of the water”. She stated that she is better at math now, and reported that she had been previously turned-off to math. If the math did not apply to her, she reported she did not understand it. This student’s responses support the research of Trujillo and Hadfield (1999).

What was so very interesting about this pre-service teacher was she reported that the Math Center had a positive effect on her. This pre-service teacher's concept knowledge map responses demonstrated an increase in mathematical understanding as the Number Operation responses decreased and the other NCTM strands increased. This suggested that the Math Center did have a positive effect on her. Although her responses to mathematics broadened from pre-visit to post-visit testing, they did not include any attitude responses, and her anxiety level did not significantly improve. The pre-service teachers visited the Math Center three times during this study and were students of the researcher. This suggested that improvement in mathematical understanding does not necessarily precipitate increases or improvements in attitudes or math anxiety levels. The implication is that, in young adults, high math anxiety and negative attitudes toward math are difficult to change, accumulate, and require extended treatment. These findings when combined with brain research studies regarding learning mathematics necessitate the conclusion that preventing anxiety and the accumulation of anxiety could be a key factor in improving student achievement in mathematics.

In-Service Teacher Results. The in-service teachers experienced a lessening in their average anxiety level from 2.32 at the pre-visit administration to 1.92 at the post-visit administration. Although only two teachers completed the post-post visit testing, the anxiety level continued to decrease from post visit to 1.78 post-post-visit. The in-service teachers reported no Negative Attitude responses on the concept knowledge map. This appeared to align with the results from the MAS-R. The Attitude Positive responses decreased from 7.3% at the pre-visit session to 3.2% at the post-visit session. The post-post-responses increased to 6.2%; however, two teachers composed the post-post-group.

From these results, it appeared that the visit to the Math Center benefited the in-service teacher participants.

The study results indicated that teachers with higher anxiety levels tended to have students with higher anxiety levels, and teachers with lower anxiety levels tended to have students with lower anxiety levels. Hill et al., (2008) research concluded teachers who are mathematically proficient, are more effective mathematic instructors than teachers who are not mathematically proficient, and teachers who are not proficient in mathematics have higher anxiety levels. The implication is that teachers with high anxiety require treatment to reduce math anxiety. A recommendation would be to conduct further studies by providing treatment to teachers with high anxiety levels and the effect on student achievement.

Falk and Dierking (2000) and Melber and Abraham (2002) concluded that high quality communication between museums and schools translates into better visits for the students. The Math Center provided pre-visit information to all teachers prior to visiting the Math Center. The goal of providing this information is to ensure a successful field trip experience for the teacher and the students. Dewitt and Osborne (2007) concluded in a study of enhancing the effectiveness of field trips a list of six steps educators should follow for field trip visits. Briefly the steps are for the educator to: 1) become familiar with the setting; 2) orient students and clarify learning objectives; 3) implement pre-visit lessons; 4) allow time for students to explore during the visit; 5) plan activities that support curriculum; and 6) implement post-visit lessons.

The pre-visit interviews of the teachers inquired about the effectiveness of the information supplied by the Math Center to plan the visit and the preparation the teachers had implemented towards the success of the visit. The first few questions of the interview specifically addressed the quality of the information. The teachers who had not previously visited the Math Center, although invited to so, did not preview the Math Center before the visit. All teachers reported that they had or would be discussing the visit with their students. The teachers reported that they needed help, had questions, and/or felt the pre-visit information was a little overwhelming.

During the post-interview, the pre-visit information was revisited in order to inquire about the best way to make improvements to the information. The teachers reported that they had not implemented any pre-visit lessons. Each educator was asked to make selections from a menu for several activities in order to specifically support their instruction and curriculum. The teachers reported that being able to choose activities aligned to their grade level and curriculum was an important feature of the Math Center. The pre-visit information provided the teachers with post-visit activities to implement after the visit. All teachers from School B3 utilized a post-visit activity with their students; however, the teachers from Schools A1 and A2 did not utilize the post-visit activities. The teachers reported during the post-visit interview that the pre-visit information was “dead-on”. Although the information provided by the Math Center addressed the Dewitt and Osborne steps, the teachers did not utilize the pre-visit information. Further investigation needs conducted as to the best format and media to use to deliver the information. Perhaps it would be best to deliver the information via a video on the Math Center website. The conclusion is that the information provided to the teachers needs revised to ensure the teachers utilize the information to gain the most benefits for the students.

The research for this study was conducted in the spring of 2011 prior to the administration of the MAP test, the state assessment test. All teachers who administered the MAP test reported choosing the menu activities based on practice or review for the test and their focus for the visit was the MAP test. With the focus on the MAP test, the impact of these choices, if any, needs further research.

The Design…Does it Connect the Body of Knowledge (Formal Education) with the Body of Experiences (Informal Education)?

The pre-service teacher and in-service teacher post interviews and focus group interviews yielded valuable information regarding the visit to the Math Center and the bridge between informal and formal education. Several themes emerged from the interviews. The most evident theme that emerged focused on connections, and the other themes that emerged were alignment to curriculum and engagement of the students.

The connection theme focused on learning between the classroom and learning in the Math Center. There were six types of connections described: exhibits and activities to math instruction; exhibits and activities to student schemata; math and the real world; math is everywhere; learner to mathematics; and the opportunity for future connections between math and the Math Center. The predominant type of connection noted referred to the connection between the exhibits and activities in the Math Center with math instruction in the classroom, "Do you remember this when we visited the Math Center?" The second type of connection reported referred to the students and the connection between their schemata and the exhibit. "The one with the geometry and the shapes and the solids, my kids really connected with that one." The third type of connection reported referred to the connection the students made between mathematics and the real world. "I just tried to bring it in and connect to real life which it was as they experienced at the math lab." The fourth type of connection referred to how the students made the connection that math was everywhere, but the teacher was not sure that the students understood that the math was like math done at school. The fifth type of connection was a personal connection to mathematics. A pre-service teacher stated, "It made more connections, not just for the students to see how the math works, but for me as a future educator as well." The last type of connection referred to the opportunities for connections that can be made by the teacher at some point in the future. The research of Hinton et al. (2008) and Jensen (2005) concluded that connections in the brain strengthen, weaken, or dissipate depending on the activation of these connections. This research indicates that connections made in the Math Center strengthen the learning of mathematics in the students and in instruction, and therefore, connect math in the formal and informal educational settings.

All teachers reported that the exhibits and activities aligned with their curriculum in the school. In fact, the fifth grade teacher reported, "I didn't see one thing that would not align with the fifth grade curriculum," and the third grade teacher from School A2 said, "there were tons." As previously discussed, Dewitt and Osborne's (2007) research concluded that field trips aligned to the curriculum increase the effectiveness of the field trip visit. Kisiel's (2005) research suggested that field trips that align with the curriculum improve student interest and motivation. The design of the Math Center planned for curriculum alignment, and this alignment creates a connection between the formal and informal educational settings.

The other theme that came forth in the interviews referred to motivation and the engagement of the visitors. This theme emerged from the question about the effect and/or impact of the giant-sized exhibits. Within this theme, the participants referred to the physical movement or active participation of the visitor; the opportunities for visitors to participate in teamwork; demonstration; and the added excitement from the giant-sized exhibits. The fifth grade teacher reported, “It drew them in pretty much.” One pre-service teacher reported, “I think they help with attitude.” Another stated, “you can have five or six people working as a team.” Another pre-service teacher mentioned, “you associate the moving of your body with it.” A final comment from the pre-service teachers stated, “I think that one person that is actually doing it can kind of demonstrate to a lot of other kids how to do it…how they are working it out”. The third grade teacher from School B3 discussed how the giant tangrams got the students excited, and how back in the classroom, the students are still working with classroom tangrams to figure out how to make the square. “They really wanted to do the big ones…just added that excitement”.

The in-service teachers discussed the importance of the giant-size exhibits during the focus group interview. “It is really important” and “It gets their attention right away.” The independent evaluator had shared that he believed the kids went to the activities they knew how to do, but an in-service teacher thought the students went to the biggest activities right away. This in-service teacher continued, “It’s big…It’s there. Yes, I think big is important. My crew played Chess, but only with the large Chess set.” Based on the research of Falk and Dierking (2000) that stated good design draws the visitor in, and the research of Caban et al. (2000) that stated the most remembered learning engages the emotions and as intensity increases so does the education value supported the use of the giant-size exhibits. This study demonstrated the importance and effectiveness of the giant-size exhibits in motivating and engaging the visitors as well as providing a higher educational value, therefore, the giant-size exhibits connect or bridge mathematics in the informal and formal settings.

The piers of research supported this bridge – Math Center. The results from the MAS-R inventory and concept knowledge map cemented the bridge deck to the piers, and the information gained from the interviews further strengthened the bridge deck. The bridge between the "Body of Knowledge," formal education, and informal education, the "Body of Experiences" paved the way for students to cross into a new mathematical understanding.

The Forces of the Nature of Education Erode Student Understanding of Mathematics

The results of this study provide insight to examine the problem of improving student achievement from previous research over the past 40 plus years with a different perspective and best define the problem that mathematical educators face in improving student achievement. The anxiety levels of the pre-service teachers were by far the highest of the three groups of participants in this study. These results speak to the magnitude of the problem. Anxiety is caustic and accumulative. Regardless if anxiety has an acute onset, builds in students throughout their school careers, or both, approximately 75% of students graduate from high school with mild to severe math anxiety. These students do not pursue careers in STEM fields. This is not due to a lack of ability, but rather the lack of positive experiences with mathematics. In fact, some of these students become future educators. The researcher has created a cycle that demonstrates the cyclic problem, the cycle of anxiety. See Figure 51.

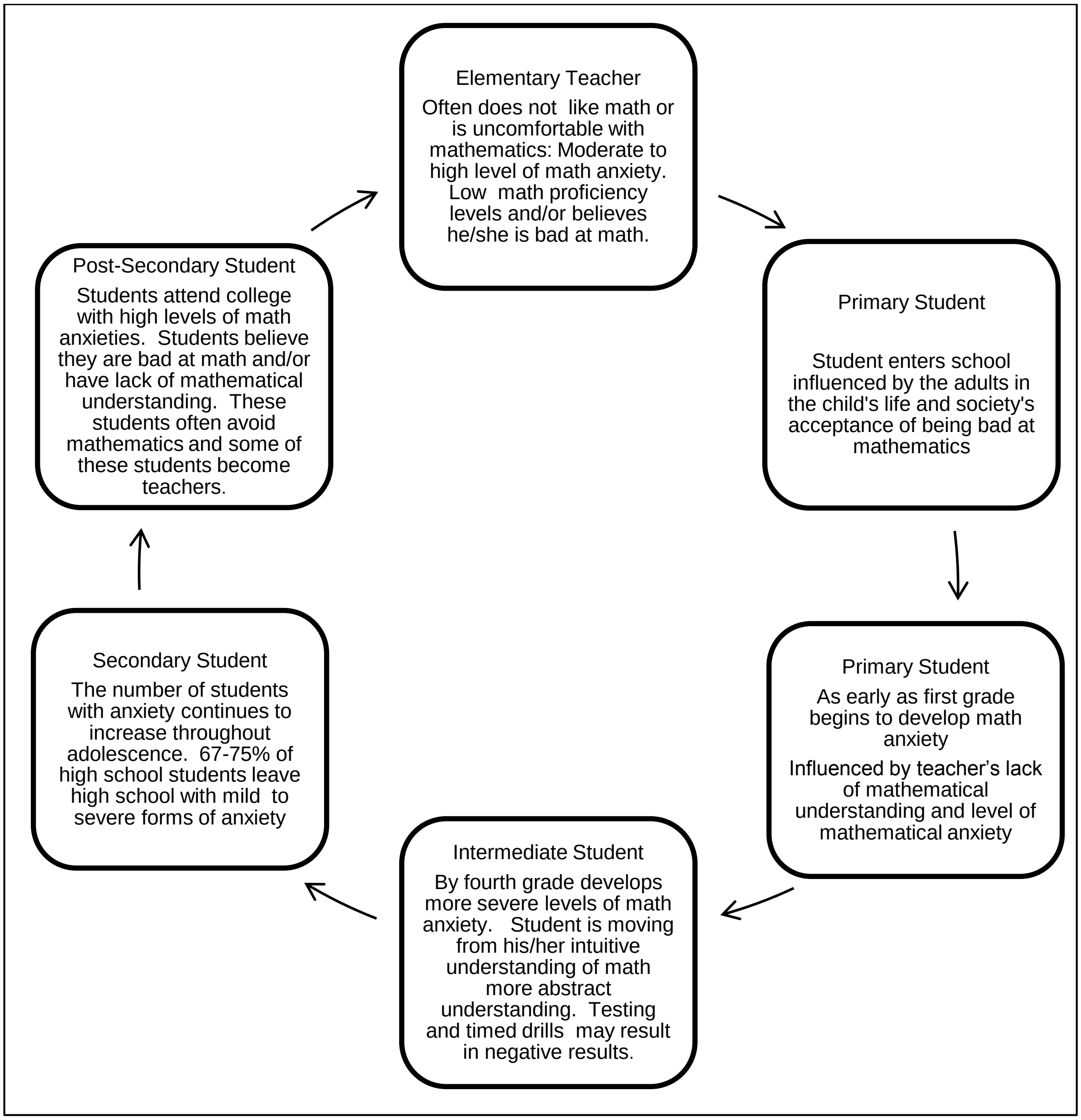


Figure 51. The Cycle of Anxiety

Students may enter the cycle at any point, and research from the National Research Council (1989) suggested that the most common entry point is the lasting memory from the last unpleasant course taken. What drives anxiety? Negative experiences with mathematics drive anxiety. For each student there are different reasons; however, each reason is associated with one or more parts of the cycle.

The research for and the results of this study demonstrated that an educator's beliefs, skills, biases, attitudes, and anxieties about mathematics are directly or indirectly communicated to the students. A teacher who is proficient with mathematics produces students who are proficient at math. Assessments intended to evaluate understanding may actually accelerate math anxiety. Societal acceptance of being not good at math is fueled by perceptions that math is difficult for those not math inclined as peer pressure is placed on students who perform well in math and widespread fears of "new math" continue rigid views of mathematics.

Math instruction currently feeds the cycle. Best practices in mathematics do not address or acknowledge math anxiety. The results of this study concluded that levels of high anxiety exist in all sectors of the population. The way the brain learns requires a positive environment; however, many educators are not aware of the toxicity of anxiety. When math anxiety exists, a self-imposed invisible negative force field surrounds the learner. The learner is not able to absorb the material when their brain, unbeknownst to the educator, prevents them from learning. This unknown anxiety sets in motion more failure and thus more anxiety.

Anxiety will not go away overnight; however, the first step is to educate our educators about anxiety and its toxic effect on students. Mathematics educators at the secondary and post-secondary levels most likely do not suffer from math anxiety and as such may not have a clue as to the toxic levels present in classes they are instructing.

These instructors will need resources to assist their students with anxiety and resources for tutoring students who need to build a solid understanding of mathematics that will support advanced mathematics. In addition, post-secondary educators will need training on classroom and instructional practices that do not produce math anxiety.

Mathematics educators at the early childhood and elementary levels need to assess and address their level of math anxiety through training. In order to become math proficient and build mathematical proficiency in students, all early childhood and elementary educators should continue to work with and practice mathematics at a middle school level in ongoing professional development. This does not include professional development for implementing a new series or methods of teaching mathematics. It includes meaningful practice that employs the extensive use of manipulatives and guides the educator to discover how math works.

As educators address their levels of anxiety and proficiency levels, the next part of the solution is to address math anxiety in all students. This includes guiding students through their struggles with mathematics, encouraging the students to embrace the struggle, and building mathematical understanding through the self-confidence gained from working through the struggle. In order successfully guide students through the learning process of mathematics, educators need to use assessment to motivate the students to learn mathematics and not develop math anxiety.

As long as math anxiety remains unaddressed by education, the cycle of math anxiety will continue. As long as education continues to produce students with math anxiety, student understanding of mathematics and achievement in mathematics will not improve at a rate required to ensure America’s position as a global leader.

The Model for Building Bridges

This study demonstrated the need and the effectiveness of The Metamo4ic Math Center. Metamorphic says it all. A metamorphosis is not only a change. It is a transformation. Butterflies undergo metamorphosis. A butterfly begins when an egg is laid, hatches into a caterpillar, enters a chrysalis, and then emerges as a butterfly. The views of mathematics and the state of mathematics education in the United States are in the caterpillar stage. The Metamo4ic Math Center was created to move mathematics into the chrysalis stage, and then have math emerge as an appreciated subject in which negative attitudes and anxiety toward mathematics are changed and transformed into appreciation for the subject that in turn build mathematical understanding.

The Math Center served as a model that bridged informal and formal education until being displaced by a tornado just after the completion of this study. Bridges make connections, and the Math Center, discussed as a bridge, made connections from mathematics in the school to mathematics in the Math Center, a museum setting.

Recommendations for Future Research. To address some the limitations associated with this study, there are several possibilities to consider. First, an independent evaluator should be employed to conduct future research. This removes the cloud of doubt surrounding researcher bias. Second, dedicate one trained staff member to administer the testing instruments in each school. This creates consistency and eliminates discrepancies due to differences in communicating the instructions to the study participants. This also permits the timely collection of data. Third, research on developing an effective math anxiety inventory instrument for primary students would lead to diagnosing math anxiety in primary students with more ease. In addition, this would permit the tracking of math anxiety levels at any school. Finally, expanding the size and demographics to include at least two school districts from three distinct socio-economic levels would improve the comparisons and conclusions of the data. In addition, this would cause a larger sample size, which would better represent the total population.

Recommendations for Change and Modifications to the Math Center. As the Math Center is now in the rebuilding stage due to the damage done by the tornado, an opportunity from the loss becomes the possibility for the future. As previously stated, this study revealed that the educator guides for the field trip visit need to be revised. The information in the guide needs to be consolidated and concise so that the educators are not overwhelmed and feel inclined to read it. In addition, a video clip for the teachers and field trip chaperones to access from the Math Center website would add the visual images that would assist the teachers as well as benefit the students.

This study did not directly investigate the instructions and/or directions for the exhibits and activities, but the study did confirm that students did not always read or follow the directions. Therefore, as the Math Center undergoes reconstruction, so will the instructions. The researcher will implement the use of pictorial illustrations and diagrams to reduce confusion, encourage faster engagement, and permit the non-reading visitor to understand what to do at the exhibit. However, it is important to remember that part of the beauty of the informal educational setting is that the visitor selects how he or she engages in the activities and exhibits. The wonder of the museum should never be compromised by the forcing a visitor to explore ideas and concepts with limitations. There were many wonderful ideas gained from young visitors who chose to interact with exhibits in their own unique ways. The use of audio headsets, MP3 players, will be implemented to improve the quality of the visit. Several exhibits would be more effective if voice directions were available.

Finally, the researcher will have the opportunity to design and create many more exhibits and activities that were a dream in the proto-type facility. A 15,000 square-foot building was donated to the Math Center to create the dreams envisioned when the Math Center was founded. Some of these exhibits expand the conceptual understanding of mathematics while others expand the marvels of mathematics. Regardless, the designs will be giant-size exhibits. The study strongly demonstrated the positive effects of the giant-size exhibits on attitude as well as learning. Simply put, the giant-size exhibits caused the students to become a part of mathematics.

As the board and staff of the Math Center work to raise the funds to renovate the donated building to reestablish and reopen our physical location, we continue to operate by providing our services on location. The importance of our work has now emerged. The significance of the giant-size exhibits and math tools in children learning mathematics, which we are unable to transport as we visit other organizations, is the motivation needed to continue the mission. The plans to reestablish the Math Center do not end with the facility in Ferguson, Missouri. The model is replicable so that students, teachers, and parents from around the United States will have places to go that provide mathematical experiences that eliminate math anxiety and negative attitudes toward math and shows kids of all ages how math works.

Conclusion

This study examined the effectiveness of a two-hour visit at a Math Center. The results demonstrated that the Math Center lessened anxiety and positively changed attitudes toward mathematics. Although, the researcher suspected that the cycle of anxiety existed, she did not realize that this study would provide the evidence of the cycle of anxiety. Once American education embraces the toxicity of the cycle of anxiety and implements corrective practices, student achievement in mathematics will increase and the needs of the country will be met as students who once might not have pursued a STEM career will do so.

Once it is understood that the weaknesses in math are not based in the lack of ability, but rather in the lack of positive experiences with mathematics and beliefs that one can be good at math, basic mathematical understandings that lead to understanding advanced mathematics will become ingrained in American schools. The cultural acceptance of math illiteracy will dissipate and then cease to exist; thus, ending the contagious cyclic instruction of mathematics that is currently present in American society and schools today.

Appendices

Appendix A

Best Practices for Teaching Mathematics

Furner, Yahya, & Duffy, 2005

- Teach vocabulary using real objects and demonstration
- Relate math problems and vocabulary to prior knowledge and background
- Apply problems to daily life situations
- Use manipulatives to make problems concrete
- Encourage drawings to translate and visualize word problems
- Have ELL/special education students pair with typical students for computer/cooperative activities
- Have students write original word problems to exchange with classmates
- Explain directions clearly, and repeat key terms
- Encourage students to follow the four-step problem-solving process
- Realize that not all math notations are necessarily universal
- Group students heterogeneously during cooperative learning
- Make interdisciplinary connections to what students are learning in math
- Make cultural connections for students when teaching mathematics
- Rewrite word problems in simple terms
- Concretize math concepts with Total Physical Response (TPR)
- Create word bank charts and hang them in the classroom for viewing
- Take Internet field trips and use mathematics software
- Use children's literature to teach mathematics and develop the language
- Using auditory, visual, and kinesthetic learning teaching approaches for different learning styles enables teachers to reach more students than the traditional direct-instruction or paper and pencil drill and practice forms of instruction

Appendix B

Metamo4ic Math Center Survey

The Metamo4ic Math Center

This proposed Center is being designed to promote how math works and to foster math appreciation in children. The plans are to locate this facility in Historic Downtown Ferguson. There is ample free parking and school buses should have no problems with loading or unloading students. The focus of this facility is to make math a hands-on life-size experience with the use of giant size manipulatives and games that cover math concepts as exhibits (geometry, data analysis and probability, number properties and operations, measurement, and algebra). The core of the facility will be a historical exhibit of math which will feature a mathematician of the month. In addition, we are planning to have Challenge Rooms for students who visit the facility on a field trip outing. Educators will be able to select activities appropriate for their students and/or topic of study from a menu. Educators will also be given the choice of selecting one specific topic or combining a variety of topics and activities. Each Challenge Room will be able to accommodate up to 32 students at one time. The admission fee includes a visit through the facility and also the educator-selected activities in the Challenge Rooms. (Activities will be leveled from the first to the eighth grade.) As we move forward with our plan, we would appreciate your input to help make this facility useful to you as an educator. Thank you for your time and input!!!

Name of School ____________________________________ Grade Level(s) _______
Name of District ____________________________________ Subject ____________

1. I think this math hands-on museum facility is an innovative and unique idea and would be of benefit to the St. Louis Metropolitan Area.

   Strongly Agree   Agree   Maybe   Disagree   Strongly Disagree

2. I think the opportunity to take my students to a mathematical facility that my students can tour and then makes activities specialized to my needs and the needs of my students would be useful to me.

   Strongly Agree   Agree   Maybe   Disagree   Strongly Disagree

3. I would plan on taking my class to The Metamo4ic Math Center in the 2006-2007 school year.

   Strongly Agree   Agree   Maybe   Disagree   Strongly Disagree

4. I believe my colleagues would consider taking their students to the Center in the 2006-2007 school year.

   Strongly Agree   Agree   Maybe   Disagree   Strongly Disagree

5. I believe a $4.00 per student fee, a 20% discount, would be a fair admission price.

   Strongly Agree   Agree   Maybe   Disagree   Strongly Disagree

---

□ Please send additional information to ____________________________________
____
____

□ I would like to schedule a field trip please call me at (   ) ______ - ___________

□ I have provided additional comments on the back of this paper.

Appendix C

Exhibit List

Exhibit/Activity	Description
Red Room	
Story of Math	
Timeline	A child friendly narrative about the story of math in chronological order.
Base Ten, Baseball, or Off Base?**	A narrative about how our number system is based on 10-digits.
Famous Mathematician	A narrative about an individual who advanced mathematics. The mathematician changes monthly.
Oh No It's a Set-Up	A narrative about how the numbers in our number system are grouped into sets.
Napier's Bones**	These "bones" are giant-sized recreations of a calculation device created by John Napier for multiplication and division.
Hocus Abacus Pocus	This giant-sized reproduction of an ancient Chinese calculation device is used for addition and subtraction (Place values are color-coded)
Math Town	
Addition Hotel	Digits make families of numbers. Play hotel and add numbers.
Subtraction Hotel	Digits make families of numbers. Play hotel and subtract numbers.
Base Ten Motel	Discover the patterns of numbers. Make and read numbers.
Number Operations Games	Use a 100 or 144 space grid and connect 4 or 5 numbers in a row by rolling two dice and using number operations to place tokens on the board.
Simply A-Maze-Zing	Work together to move a ball from one end of the maze to the other. The highest score wins
Number Flip	Roll the dice, flip over numbers, and the lowest score wins
Snakes and Ladders	A game that has kids counting to win.
Launch Pad Frogs	An activity that builds motor skills and has kids counting
Hum Ringer	Toss Dice in a hoop...The first to score 21 wins
Shuffle Putt	Putt, play shuffle-board, and score
Giant 15 Puzzle	Align the numbers in order and/or for all rows/columns to equal 30
R U Up 2 Par? Divisibility Rules	Arcade golf game.

Measurement Mania	
Thermofun	A giant-sized thermometer with Fahrenheit and Celsius readings. Practice setting everyday temperatures or conversions.
Three Strikes You're Out	This activity requires two visitors to work together to calculate strike zones.
Make A Snake	Practice measurement to the nearest inch, 1/2 inch, 1/4 inch, or 1/8 inch by measuring to build a snake.
Foot Loose	Three different sized feet are used to estimate distance between two arrows on the floor.
Jump	This floor ruler is used to predict and estimate distance of a long jump.
Car Wars**	Use instructions to build a shoe-shaped car from construction rods and connectors. Roll, time, and calculate car's speed.
Shop Til You Drop	A store vignette to practice estimation, using money, and making change. Red activities include calculation of sales tax.
Show Me the Money	This game is for 2-4 players to practice working with money.
It's About Time	Use your arms and hands to make time. A giant-sized clock to practice telling time and figuring elapsed time.
Measure Island	An island of measuring opportunities to work with different measurement tools in both metric and customary systems.
Hopscoinch	Hopscotch to identify (heads/tails or coin name) or add coins when hopping.
Measure Treasure	Treasure to weigh both mass and weight in both metric and customary systems.

Exhibit/Activity	Description
Orange Room	
Dazzling Data	
Bowling for Data	1-4 Players take turns bowling, record the data, and if appropriate, calculate mean, median, mode, and range
Data Daily Question	Question selected by field trip coordinator and each visitor adds his/her piece of data. Results sent back to school.
Probable Probability	
Snake Eyes	Roll the giant-sized foam dice and determine the chances of rolling snake eyes.
Probability Park	Play baseball using a giant size dice. What is the probability for getting on base or making an out?
Wanna B a Baseball Manager?**	Discover the possible combinations for a line-up of 9 players.
Pascal's Triangle	Look for patterns within this famous triangle: Addition, Fibonacci numbers, Multiples, and Probability Predications
Awesome Algebra	
U B an Equal Sign	Use buckets and weights to experience what the equal sign must feel like in an equation.
Roll It, Build It, Solve It	Teams of two will roll the foam dice, build equations or number sentences, and solve when appropriate
Cartesian Coordinates	Two players take turns rolling foam dice and covering coordinates looking for a win of 4 in a row.
Function Machine	Two players work together as one feeds in the function the other sends out the answer.
Picnic With Pythagoras**	Use the right triangle and picnic plates to observe how the Pythagorean Theorem works

Gigantic Geometry	
Stretch Your Knowledge	Two 3 feet square geoboards to build polygons, work with symmetry, or add, subtract, multiply, or divide fractions
Which Way Do We Go?	1-4 Players operate a remote control car following a set of directions to a common destination.
Sort the Solids	Use the large foam solids and sort them by various attributes (edges, faces, shape, etc.)
Shape Up or Sort Out	Sort the gigantic polygons by color, shape, size, or symmetrical characteristics. Further investigate triangles and quadrilaterals.
Pentominoes	Use provided squares to make all the possible combinations of pentominoes. Use the pentominoe shapes to solve puzzles.
U B a Vertex	Visitors work together to create geometric shapes.
Beam Me Up a Solid	Use the construction set and build geometric solids.
Pattern Blocks	Blocks to learn shape recognition, equivalence, rotation, transformation, similarity, symmetry, perimeter, and area.
Pattern Block Games	2-4 Players per game. Players use pattern blocks to cover a board design and be the first player to use all their pattern blocks.
Geocube	Work on team building and problem solving skills with this giant cube.
Fractions, %'s, and Ratios	
The Versatility of One**	Discover how all fractions are changed to equivalent forms.
Fractions and Tangrams	Use tangram puzzle pieces to discover how they are related to the whole.
Fractions in Action	Spin the round discs painted with different proportions of red, blue, and yellow. Compare the different colors they create

Exhibit/Activity	Description
Yellow Room	
The Young Child	**Designed for Children Pre-Kindergarten - 8 Years Old**
Dominoes	2-4 Players - Leveled games include one-to-one correspondence, patterns, matching, and the game of dominoes.
Tall, Taller, Tallest	Place the canisters in order of small to large
Big, Bigger, Biggest	Place the shapes in order of small to large
Small, Smaller, Smallest	Place the shapes in order of large to small
Castle Blocks	Create symmetrical and asymmetrical castles
Here Fishy Fishy	1 or 2 Players - Leveled games include catching fish by color, shape, number, addition, subtraction, and multiplication
Math Sense	Visitors use tweezers to pick up specified geometric shapes and also reach into a clown's head to feel for geometric shapes
Feet By the Foot	Estimate (guess) how many feet from one wall to the other. Use one foot and measure to check.
All Sorts of Fun	Use the rings to sort objects by size, shape, color, or any other attribute.
The Four Penguins	Division for little ones.
Story About a Rooster	An adult reads the story to 1-4 little ones. Children use the animals to figure out how many animals went around the world.
Equal Equations	Children use magnetic numbers and shapes to create number sentences. Children may also create a story problem.
Tall Funny People	2-4 Players roll a die and build the tallest funny person possible.
Hopscotch	Children hop or jump on each square naming the number, name the number as odd or even, or adding numbers as they hop.
Suitcase Sort	Children sort and pack clothes to match different weather situations
It's In the Cards	2-4 Players - Leveled games include color matching, concentration, greatest number, and attribute matching.

The DaVinci Mode	
Probots	2-4 Players program a robot to create squares and rectangles. At a middle school level, children may program the robot to make other polygons with knowledge of exterior angles.
BeeBots	2-4 Players program a robot to follow a given sequence of shapes or coins
3-D Construction	2-4 children build polyhedrons and then may dissect the shape to determine its net
Magnetic Square	2-4 children use triangles, squares, and circles to create symmetrical and assemetrical designs
Mirror Mirror on the Wall	Use paper and the mirror. Write your name on the paper so that it appears correct in the mirror.
Spiffy Spirals	Create designs using string and numbered pegs
Box by Box	Use grided paper and trnasfer a still-life arrangement sitting behind a clear grid box by box to the paper
Round and Round	Use this 24 inch giant spirograph to make endless circular designs
Spin Art	Use a spinner and a paper plate and create circles of all sizes
Fibonacci Facination	Where can you find the Fibonacci sequence?
Can Straight Lines Make Curves?	Use the axes and see if straight lines can make a curve.

ART PROJECTS	
Ceaseless Circles	Create cycloids and cardioids.**
Quasi Quilts	Quilts tell stories. Design a quilt block that tells a story about you. Will it be symmetrical or asymmetrical?
Face It It's Gold	Learn about the Golden Proportion or Ratio. Use the provided face and see if it's gold.**
Whacky Wallet	Measure and/or use pre-cut pieces and make a wallet that works like magic
Steppin Through	Step through a 9x12 piece of paper. How? Follow the directions and step right on through! **
Terrific Tessellations	Use a 41/2 inch square and create a shape to tessellate. **
Magnificent Mosaics	Use the colored squares and glue sticks to create a unique mosaic.
Making Time	Use the stamps to make time
Stencil City	Use the stencils and create a building for a city
Architect Adventure	Use the dado blocks and try to create assymetrical and symmetrical buildings
Math Story	Use the stamps and stamp pads and create a math story
Book Worm	Use a ruler, measure the tape, and create a book worm picture
Dissecting Quadrilaterals	Take a giant square and dissect it to discover the properties of quadrilaterals
Origami	Make a whale or a penguin from a sqaure of paper
Math Mural	Use watercolor crayons, spinning marker tops, and roll on paint to create a math mural
Symmetrical Sort	Sort the alphabet into symmetrical and assymetrical stacks
100 Boxes	Create a design from 100 boxes
Blown Out of Proportion	Blow up a balloon, draw a detailed picture on it, let the out...watch what happens.
Math and Music	
Body Counting	It's like dancing with numbers. Body-count with numbers from 1 to 27.
The Keys to Making Music	Look at poems, instruments, and lyrics. What patterns emerge?
Music in the Round	Experiment with musical instruments in a round setting.

Exhibit/Activity	Description
Green Room	
Get Your Game On	
Arithmathtricks	Math tricks to try out
Nim	An ancient Chinese game. Two Players - Four Versions. Play and play to figure out the always win strategy.
Card Games and Tricks	Giant-sized cards to play math games or figure out how card tricks work.
Dominoes	2-4 Players - Play the traditional game of dominoes or try some mathematical variations
Giant Toothpicks	Arrange the giant sticks and then solve the puzzle.
Arrolle Cinco Dados	Roll 5 dice and decide how to score them following the requirements for the game.
Metamo4ic Math Game	2-4 Players or Teams - 16 can play at one time if teams are used. Build and score equations to win with the most points.
Native American Game Sticks	2 Player Game - This is a Native American game of probability.
Kalah	2 Player Game - This ancient game is also known as Mancala. Develop winning strategies.
Alignment Games	2 Player Games - 4 Versions
Hex	2 Player Game - Can you develop a strategy to win while keeping the opponent from winning?
Make Nine	2 Player Game - Place the numbered discs in the game board to get 4 markers in a row that add up to 9.
Checkers - 3 foot game	2 Player Game - Play the traditional game, play to lose, or play diagonally.

Chess - 5 foot game	2 Player Game - Learn who the army of players are. Learn how to set up the board. Play a game. Use the Algebraic Notation.
Chess - 3 foot game	2 Player Game - Learn who the army of players are. Learn how to set up the board. Play a game. Use the Algebraic Notation.
Tangrams	3 foot square tangrams. Can you assemble the 7 pieces into a square or rectangle? What shapes are congruent?
Giant Colored Sudoku	Solve Sudoku puzzles.
How Sweet It Is	Use pieces of candy and look for color attributes. Two versions.
Kono	Korean game of strategy.
Solitaire - The Cross	Can you remove all but one game piece?
Solitaire	Can you remove all but one game piece and end by landing on the blue star?
Twisted Tic Tac Toe	Tic-Tac-Toe that is played by placing pieces on top of another, moving stacks, or turning over stacks. Three in a row wins.
Cribbage	The game of cards, math, and strategy.
Giant Chinese Checkers	Use mathematical strategies to be the first player to move your marbles to the other side of the board.
Head 4 Home	Use mathematical operations to be the first to move your pawns home.
Blokus	Play this giant size version of this spatial mathematical game.
Hall Way	
Easy Street	Math has properties. Learn about the properties of math and find yourself on "Easy Street"

Appendix D

Coordinator Planning Guide

Planning For Your Visit

We are looking forward to your visit! The following information will help you plan a wonderful experience for your children. We will send information for Adult Guides and directions to the Math Center separately.

How do I get the most from our visit?

We suggest educators and Parent (Adult) Guides tour and preview the Math Center before your visit. If that is not possible, visit the website http://www.metamo4icmathcenter.com/Photo_Tour_May_2008.html and take the photo tour through the Math Center. Here are some suggestions on how to utilize the Math Center:

☐ Research indicates that conversations promote learning. Create conversations during and after your visit. A class book created by the students is a great way to continue to discuss this experience throughout the year.

☐ Provide positive mathematical experiences to demonstrate that math is everywhere in our world

☐ Build positive attitudes towards math

☐ Introduce/reinforce and/or practice specific concepts

☐ Math Mysteries - Groups with less than 30 total children follow a map and become math detectives to solve math mysteries

☐ Go Figure Challenges - Competitions that engage older students to work together, develop a plan, and problem solve

What do we need to do before our visit?

☐ Adult Guides:

- A minimum of 1 Adult Guide per 8 children is required, but more are welcome to attend.
- For grades K, 1, and 2, an Adult Guide per each group of 3-4 children is optimum.
- Make Adult Guide Assignments. (see Adult Guide Info Sheet)
- Please inform your Adult Guides they are expected to play and work with the children while at the Math Center.
- There are no admission fees for Adult Guides.

☐ Grouping Students for the Visit:

- The activities/exhibits are designed for up to 4 students in a group.
- We recommend to group children with similar abilities together, but you know your kids best.
- Assign students to **groups of no more than 4** children.

☐ Group the Groups of 4 for Rotations during the Visit:

- Keep in mind there are four (4) rooms, and therefore, four (4) rotations. Each rotation is 25 minutes
- long.
- Decide which groups will be rotating together. This varies visit to visit and is usually determined by
- dividing the total number of children by the number of rooms your group will occupy:

☐ less than 20 total children - 1 room

- 20-40 total children - 2 rooms
- 40 - 60 total children - 3 rooms
- More than 60 children - 4 rooms

- You are also welcome to rotate by classrooms attending the fieldtrip.
  - No more than 20 - 25 children per room.

☐ Share this information with all staff who will be attending this fieldtrip.

☐ Decide on the Graph Question of the Day question. The data collected returns with you to use for instructional purposes.

☐ Decide which art projects will be on the tables and the theme of the Math Mural in the DaVinci Mode area. For you convenience, all artwork is collected and given to the coordinator at the end of your visit.

- Primary children - choose 2 projects
- Intermediate children - choose 4 projects
- Math Mural themes

☐ Decide if the children will be shopping at the Math Cart. The Math Cart supports the Math Center and has items that are math related. Prices range from $.25 to $3.00. Note: We do sell T-Shirts for $10.00.

☐ Communicate with the Math Center 2-3 days before your visit to report the final count, decisions on the Graph of the Day, art projects, Math Mural, and whether or not the kids will shop at the Math Cart.

☐ Double-check the bus reservations with the bus company/garage a day or two before your visit.

What do we do when we arrive?

☐ We will meet the bus when you arrive. Please unload by the canopy incase of rainy weather. Buses park in the parking lot closest to January Wabash Park. If you did not arrive by bus, please park anywhere in the parking lot and enter the building.

☐ When you enter the building, you may need to use the intercom to be admitted. Travel up the stairs to the top level.

☐ Everyone will gather in the Red Room for instructions for the visit.

- Children beginning in the Red Room should enter first and sit down in a line next to the Red Arrow on the floor.
- Children beginning in the Orange Room will enter next sit down in a line next to the Orange Arrow on the floor.
- Children beginning in the Yellow Room will enter next, and sit down in a line next to the Yellow Arrow on the floor.
- Children beginning in the Green Room are the last to enter, and sit down in a line next to the Green Arrow on the floor.

☐ After gathering, all visitors receive instructions to guide you visit.

☐ You will be dismissed to begin the rotations.

What do we do in each room?

☐ Play with math and have the adults facilitate the activities and conversation! Ask for thinking & don't tell!

☐ After rotating into a room, the children are to sit down and wait for direction from you and/or the Adult Guides.

☐ Assign each group a place to begin.

- Children may then self-select in teams/groups on where to move in the room.
- **OR**

- You may select the activities in which the teams are to rotate.

☐ A two-minute warning is given when time is almost up. This is not a signal to begin to clean-up unless the children have a lot to put away (ex: building materials).

☐ When time is called, please see that the room is put back in order and ready for the next rotation.

☐ Please follow given instructions and directions about rotating to the next room. Do not rotate until directed.

What do the children need to know before our visit?

☐ Encourage the children to wear comfortable clothes. The floors are carpeted, but many of the exhibits require the kids to play on the floor.

☐ If you want your children to play and build equations/number sentences using The Metamo4ic Math Game, practice and go over the rules before your visit. (Instructions and board layout provided upon request)

☐ Anything the kids make in the art area may be taken back to school to keep. Ask the kids to put their name on their project and place it in the Take Home Basket in the art area.

☐ Reading is an important part of the experience. Encourage the children to read the directions. Consider an Adult Guide per group if your kids are non-readers.

What do we do at the end of our visit?

☐ You will need to decide how to exit the Math Center. You may

- Reassemble in the Red Room.
- **OR**
- Exit the Math Center room by room when directed.

☐ You will be given the artwork, mural, data for the day, and brochures to send home with the kids as you leave the Math Center.

What can we do to extend what we have learned and discovered after our visit?

☐ Learning continues to happen when communication occurs. Create a class book of your field trip experience to utilize and refer to during math instruction to cause mathematical discussions.

☐ Display the Math Mural and have the children write a story about their person on the mural. Older children should identify and discuss the shapes used to create their person

☐ Analyze the data from the Graph of the Day by graphing, averaging, finding percentages, or ratios from the data collected. Compare and contrast the data. Hypothesize and justify reasons for the results of the data collected.

☐ Have the students write about their favorite or least favorite exhibit/activity and ask them to change one thing about it, why they chose that particular thing to change, and discuss how it would make the exhibit/activity change.

☐ Have the students research and investigate a famous mathematician. Have a Famous Mathematician Math Fair. Let the kids play the role as their famous mathematician and speak to other classes and/or parents.

☐ Have the students evaluate what areas/concepts of mathematics they need to practice. Ask them to develop and implement a plan to practice.

☐ Go outside and find math in nature. Have the students write and illustrate a story about math in nature.

☐ Have the students create a cartoon that might teach another student about a mathematical concept in which the class is working.

☐ As a cooperative small group project, have the students create a mathematical game. The students must create all the necessary parts and write the directions. After all the games are completed, the students can spend time playing each other's games.

☐ Have the students write down one answer to the following (use what is appropriate for your students and modify the list as needed):

1. number in inches (example 6 inches)
2. number in centimeters
3. a temperature in Fahrenheit
4. a temperature in Celsius
5. any number
6. a square root
7. a name of a polygon
8. number of an angle in degrees
9. number in pounds or ounces
10. number in liters

Have the students trade papers and say, "Here is the answer, what is the question?" Have the students write possible questions for the answers provided

Appendix E

Adult Guide Information Sheet

Dear Adult Guide:

Thank you for volunteering to be a parent guide for the field trip to The Metamo4ic Math Center. Your facilitation and assistance with the students will make this field trip a fun, exciting and educational experience. **Please note: The Math Center expects your supervision, participation, and interaction with the children during the field trip experience**.

☐ You will be rotating with the children and the following kids are in your group:
(Recommended for Pre K - 2nd Grade)

☐ You will be stationary and assigned to the following room:
(Recommended for Third Grade and above)

___________________________________ Room

You are welcome to make an appointment or come thirty minutes to an hour ahead of the kids should you want to preview the Math Center before your scheduled visit. **Please email vicki@metamo4icmathcenter.com or call 314-807-3290, should you wish to arrange to preview the Math Center before or the day of the visit.**

OR

Visit the website and view the photo tour:
http://www.metamo4icmathcenter.com/Photo_Tour_May_2008.html

Guidelines to follow as you work with the kids:

1. Make sure the teams follow the “Rules of the Road”. It is important that kids share exhibits and work cooperatively, put back what is used for the next visitor to enjoy, and do not run in the math center. Please make sure the children handle all equipment and tools in an appropriate manner. Please stop any abusive handling of the equipment or tools immediately. If you need any assistance, please ask a teacher in the room or any Math Center Helper for help.
2. We believe that all children can be good at math. Experience and continual practice determines a child’s success. Mathematicians work every day for solutions to problems that no one has been able to solve. After all, if they are so “smart” why can’t they figure it out? It isn’t always about being smart. It’s about “stick-to-it-ness” that counts. It is okay to struggle with solutions to problems. It might be necessary to remind the kids in your group of those things. Encourage children to become comfortable with allowing a problem or concept to swirl around in their thinking. Sometimes we have to think about how we are going to solve a problem for a long time before the way to solve it becomes clear.
3. Since math is about experience and practice, it may have been some time since you have experienced and practiced some mathematical concepts. Please take this with a grain of salt. This provides you with the perfect opportunity to model for the kids that you’re not afraid of tackling math.
4. Pretend you are the coach of a team. Guide the kids to interact with the exhibits and activities and play fair. Show or read (depending on if the kids are learning to read or reading to learn) the directions/instructions to the kids and encourage them to work together at the exhibits and activities. Don’t be afraid to get in there and try to show them how it’s done even if you don’t exactly know how...showing them that learning is a life-long process is a wonderful thing to model for kids!

5. Some of the exhibits/activities provide different levels of participation for the children based on their experience level. They are as follows: Green - Little or no experience; Blue - Some experience, Black - Experienced; and Red - Challenging. You may guide the kids to choose the appropriate color or allow the team to begin at a color and work their way through more challenging levels.
6. Whether your group is learning to read or reading to learn, ask the kids to explain what it is they are to do after reading the directions/instructions. If they do not understand, try to guide them to understand or seek the help of a Metamo4ic Math Helper to assist you.
7. When working with young children, please allow them to interact with the exhibits and activities in their own unique way. These children experience the world in a way that helps them make sense of it. However, please don't allow the young child to put math center things in their mouth. (See Young Child Parent Guide Info Sheet)
8. Allow the children to do the thinking. It's natural to respond quickly to a child's question; however, asking the child, "What do you think?" encourages children to rely on and explain their own thinking.
9. The kids are assigned to a team; please try to make sure they move to exhibits and activities as a team. There are a few exceptions to this as a few exhibits and activities may be visited individually or in pairs. In these cases, allow the kids to branch off and come back together as necessary. Make sure each team does not move to a different room until it's time to rotate.
10. The children will visit four rooms at the math center. We will stop to clean-up after 25 minutes in each room. We will direct you when to rotate to the next room. Children are to sit down and refocus in each room. In teams, they are to head to an exhibit/activity, complete the activity, and then they may select other open activities to explore in the room.
11. Encourage the children to discuss math stuff. It's okay if the kids don't agree. Great mathematical understanding can come from the discussion that occurs because of a difference in thinking. However, please never allow any discussion to become an argument.
12. There are dry erase boards, markers, and erasers outside of each room and at the entrance. The kids are welcome to use these if they need to "go figure."
13. The restrooms are located off the end of the main hall. Take a left at the end of the hall and they will be to the right. Arrange for another parent guide to supervise groups while the other accompanies children to the restrooms.
14. There is a Math Mart Cart for the students to purchase math games, puzzles, and other items related to math. The items range in price from one quarter to several dollars.
15. Have fun with the kids!

Revised 10/10

Appendix F

Customizing Menu for Educators

Metamo4ic Math Center
Field Trip
Customizing Choices Menu

Customize your visit. Select a question for the Graph of the Day, theme for the Math Mural, Art Projects that support your instruction, and Game Room Activity levels that are developmentally appropriate for your students.

Graph of the Day

Description: You select one data collection question from the primary or intermediate choices below. Students have four answer choices. Girls receive pink plates and boys receive blue plates. Students place their plate in the stack that corresponds to the answer they wish to select. We will tally the data and give it to you as you leave to use when you return to school.

☐ **Primary Questions:**

- How tall are you?
  - Choices: 42 inches or less, More than 42 inches but less than 48 inches, More than 48 inches but less than 54 inches , 54 inches and taller
- What is your favorite subject?
  - Choices: Math, Reading, Science, Social Studies
- How many ping-pong balls in the jar?
  - Choices: 20-40, 41-60, 61-80, 81-100
- What is your favorite season of the year?
  - Choices: Winter, Spring, Summer, Fall
- What is your favorite sport?
  - Choices: Baseball, Basketball, Football, Hockey
- How many pets do you have?
  - Choices: None, One, Two, More than two

☐ **Intermediate Questions:**

- How many bones are in the human body?
  - Choices: 75-77, 197-199, 206-208, 274-276
- What is the third word in The Declaration of Independence?
  - Choices: Declare, Freedom, People, The
- Which measuring system is easiest to use?
  - Choices: Customary, Metric, Both are easy to use, Neither is easy to use
- How many amendments have been made to the Constitution?
  - Choices: 10, 17, 23, 27
- What number represents 10 in base two?
  - Choices: 100, 1000, 1001, 1010
- I would rather have 100 _________?
  - Choices: 0.10 carat diamonds, Dollars, Euros, Pesos

Math Mural - The children will draw/create themselves on the mural by using various math shapes. Choose from the following themes:

☐ Circle People - children use only circles and ovals

☐ Triangle Troopers - children use only triangles

☐ Polygon People - children use any and only polygons

☐ Quadrilateral Quidnuncs - children use only quadrilaterals

Art Projects

Project choices are divided into primary and intermediate levels.

- **Pre-K through second grade - choose two activities**
- **Third grade and older - choose four activities**

Even though the projects are divided into levels, you may select from either level to have activities that you feel are most appropriate for your kids. Please note selections apply for all students on your field trip visit.

Primary (choose 2)

☐ **Create a Picture** - children use cutout shapes and a glue stick to create a picture of everyday objects.

☐ **Making Mosaics** - children use square paper cutouts to create their choice of a flower, boat, house, or smiley face.

☐ **100 Boxes** - children use a 100-block stamp and colored pencils to create a pattern or color in the boxes to create a picture/design.

☐ **Origami** - children use origami paper to create a folded masterpiece.

☐ **Making Time** - children use clock face stamps and fill make time. Projects may be differentiated in specified time increments. Choose from -

- 1 minute
- 5 minutes
- 15 minutes
- 30 minutes
- on the hour

☐ **Sensational Symmetry** - children fold block vinyl letters to discover each letter's lines of symmetry.

☐ **Math Story** - children use number stamps and shape stamps to create a math story.

☐ **Stencil City** - each child uses a shape stencil to create a building. All buildings are displayed at school to create the Stencil City. This activity may be extended by asking the kids to explain their thinking and shapes used to create their buildings. If you choose this activity, you may wish to brainstorm a list of different buildings/businesses needed in a city. Have each building on an index card for each child to create.

☐ **Book Worm** - children measure colored masking tape to create a 10-inch bookworm. Choose from -

- measuring to the inch
- measuring to the 1/2 inch
- measuring to the 1/4 inch
- combination of the above

☐ **Architecture Adventure -** children use "dado" cubes and squares to explore the principals of architecture.

Intermediate (choose up to 4)

☐ **Steppin' Through** - children fold and cut paper demonstrating that as area stays constant, the perimeter can change and allow us to step through a piece of paper.

☐ **Making Mosaics** - children use up to 64 paper mosaic squares to create a design.

☐ **Advanced Architecture Adventure** - children use the "dado" cubes and squares to discover the architectural principles of proportion, balance, structure, composition, and color by solving a set of prescribed problems.

☐ **Tantalizing Tessellations** - children take a 4" square and create a tessellation.

☐ **Mobius Strips** - children make a mobius circle and discover its unique properties.

☐ **Origami Go Figure** - children experiment to see how many of the seven different ways to fold a piece of paper in half they can figure out.

☐ **Modular Origami** - children fold six pieces of paper and then assemble a cube. This is most appropriate for children in the upper elementary or middle school levels.

☐ **The Golden Spiral** - children make the golden spiral following the Fibonacci sequence and making boxes on giant graph paper.

☐ **Joy of Arc** - children work with the patterns of circles and arcs to create artwork.

☐ **Ellipse Extraordinaire** - children work with a band and two knobs on a board to create artwork from the ellipse.

☐ **Dissecting a Quadrilateral** - children remove the angles from a quadrilateral to discover the unique properties about the angles in a quadrilateral.

☐ **Whacky Wallet** - children measure and follow instructions to create an unusual magic wallet.

☐ **Box-by-Box** - children recreate a still life on paper by drawing what they see box by box in a sectioned off screen.

☐ **Archimedean Spiral** - children create and experiment with the properties of an Archimedean spiral. This activity is appropriate for middle school.

☐ **Cardiod Lloyd** - children create a cardiod, a shape used in the design of gear teeth. This activity is appropriate for middle school.

☐ **Cycloid Floyd** - children create a cycloid, a shape with many engineering applications due to its strong shape. This activity is appropriate for middle school.

Game Room

☐ **Chess, Checkers, or One of Each**

- Chess
- Checkers
- One of Each

☐ **Tiles in Metamo4ic Math Game - there are always whole number, addition, and subtraction tiles in the game bag. Choose additional tiles to be in the game bag for your visit**:

- multiplication
- division
- blanks
- fractions
- exponents
- negative exponents
- remove the subtraction tiles

Appendix G

Parental Permission for Study: Treatment Group

Lindenwood University

School of Education

209 S. Kingshighway
St. Charles, Missouri 63301

Informed Consent for Parents to Sign for
Student Participation in Research Activities

Employment of an Informal Educational Mathematical Facility to Lower math Anxiety and Improve Teacher and Student Attitudes towards Understanding Mathematics

Principal Investigator: Vicki Adams
Telephone: 314-954-8701 E-mail: vra705@lindenwood.edu

Participant ____________________________Parent Contact Info ____________________
____

Dear Parent,

1. Your child is invited to participate in a research study conducted by Vicki Adams under the guidance of Dr. S. Sherblom/Dr. William Emrick. The purpose of this research is to study if children experience a change in math attitudes and what children learn during a 2-hour visit to the researcher's informal educational facility, The Metamo4ic Math Center.

2. a) Your child's participation will involve:

- A pre-assessment of your child's attitudes towards math, at school, before a visit to the Math Center - 10 minutes
- A pre-assessment of your child's mathematical understanding, at school, using a concept map before the visit to the Math Center - 30 minutes
- A field trip visit (2-hour experience) @ The Metamo4ic Math Center located at 333 North Florissant Road, Ferguson, Missouri 63135.
- A post assessment of your child's attitudes towards math, at school, after a visit to the Math Center - 10 minutes
- A post assessment of your child's mathematical understanding, at school, using a concept map after the visit to the Math Center - 30 minutes

Approximately 600 subjects may be involved in this research.

b) The amount of time involved in your child's participation will be a total of 3 ½ hours, 40 minutes before the field trip, the 2-hour field trip, and 40 minutes after the field trip. Your child will receive free admission to the Math Center for his/her time/participation in this study.

3. There are no anticipated risks to your child associated with this research.

4. There are no direct benefits for your child's participation in this study. However, your child's participation will contribute to the knowledge about the potential benefit of utilizing informal science in instructional practices for mathematics and may help society.

5. Your child's participation is voluntary and you may choose not to let your child participate in this research study or to withdraw your consent for your child's participation at any time. Your child may choose not to answer any questions that he or she does not want to answer. You and your child will NOT be penalized in any way should you choose not to let your child participate or to withdraw your child.

6. We will do everything we can to protect your child's privacy. As part of this effort, your child's identity will not be revealed in any publication or presentation that may result from this study.

7. If you have any questions or concerns regarding this study, or if any problems arise, you may call the Investigator, Vicki Adams (314) 954-8701 or the Supervising Faculty, Dr. William Emrick (636) 949-4771. You may also ask questions of or state concerns regarding your participation to the Lindenwood Institutional Review Board (IRB) through contacting Dr. Jann Weitzel, Vice President for Academic Affairs at 636-949-4846.

I have read this consent form and have been given the opportunity to ask questions. I will also be given a copy of this consent form for my records. I consent to my child's participation in the research described above.

____
Parent's/Guardian's Signature Date

____
Parent's/Guardian's Printed Name

____
Child's Printed Name

____
Signature of Investigator Date

____
Investigator Printed Name

Appendix H

Parental Permission Form for Study: Control Group

Lindenwood University

School of Education

209 S. Kingshighway
St. Charles, Missouri 63301

Informed Consent for Parents to Sign for
Student Participation in Research Activities

Employment of an Informal Educational Mathematical Facility to Lower Math Anxiety and Improve Teacher and Student Attitudes towards Understanding Mathematics

Principal Investigator: Vicki Adams
Telephone: 314-954-8701 E-mail: vra705@lindenwood.edu

Participant ________________________ Parent Contact info ______________________

____

Dear Parent,

1. Your child is invited to participate in a research study conducted by Vicki Adams under the guidance of Dr. S. Sherblom/Dr. William Emrick. The purpose of this research is to study if children experience a change in math attitudes and what children learn during a 2-hour visit to the researcher's informal educational facility, The Metamo4ic Math Center.

2. a) Your child's participation will involve:

- A pre-assessment of your child's attitudes towards math, at school, before the study - 10 minutes
- A pre-assessment of your child's mathematical understanding, at school, using a concept map before the study - 30 minutes
- A post assessment of your child's attitudes towards math, at school, after the study - 10 minutes
- A post assessment of your child's mathematical understanding, at school, using a concept map after the study - 30 minutes

Approximately 600 subjects may be involved in this research.

b) The amount of time involved in your child's participation will be a total of 1 ½ hours, 40 minutes before the study and 40 minutes after the study. Your child will receive free admission to The Metamo4ic Math Center for his/her time/participation in this study.

7. There are no anticipated risks to your child associated with this research.

8. There are no direct benefits for your child's participation in this study. However, your child's participation will contribute to the knowledge about the potential benefit of utilizing informal science in instructional practices for mathematics and may help society.

9. Your child's participation is voluntary and you may choose not to let your child participate in this research study or to withdraw your consent for your child's participation at any time. Your child may choose not to answer any questions that he or she does not want to answer. You and your child will NOT be penalized in any way should you choose not to let your child participate or to withdraw your child.

10. We will do everything we can to protect your child's privacy. As part of this effort, your child's identity will not be revealed in any publication or presentation that may result from this study.

11. If you have any questions or concerns regarding this study, or if any problems arise, you may call the Investigator, Vicki Adams (314) 954-8701 or the Supervising Faculty, Dr. William Emrick (636) 949-4771. You may also ask questions of or state concerns regarding your participation to the Lindenwood Institutional Review Board (IRB) through contacting Dr. Jann Weitzel, Vice President for Academic Affairs at 636-949-4846.

I have read this consent form and have been given the opportunity to ask questions. I will also be given a copy of this consent form for my records. I consent to my child's participation in the research described above.

___________________________________ ___________________________________

Parent's/Guardian's Signature Date | Parent's/Guardian's Printed Name

____

Child's Printed Name

___________________________________ ___________________________________

Signature of Investigator Date | Investigator Printed Name

Appendix I

In-Service Teacher Permission Form for Study: Treatment Group

Lindenwood University

School of Education

209 S. Kingshighway
St. Charles, Missouri 63301

Informed Consent for Participation in Research Activities

Employment of an Informal Educational Mathematical Facility to Lower Math Anxiety and Improve Teacher and Student Attitudes towards Understanding Mathematics

Principal Investigator: Vicki Adams
Telephone: 314-954-8701 E-mail: vra705@lindenwood.edu

Participant________________________________ Contact Info ______________________

1. You are invited to participate in a research study conducted by Vicki Adams under the guidance of Dr. William Emrick. The purpose of this research is to determine what a visitor gains from a visit to The Metamo4ic Math Center.

2. a) Your participation will involve
   - An assessment of your attitudes towards math before a visit to the Math Center - 10 minutes
   - An assessment of your students' attitudes toward math before a visit to the Math Center - 10 minutes
   - An assessment of your students' mathematical understanding using a concept map before the visit to the Math Center - 30 minutes
   - You and your class will experience a 2-hour visit @ the Math Center in Ferguson, Missouri
   - An assessment of your attitudes towards math after a visit to the Math Center - 10 minutes
   - An assessment of your students' attitudes toward math after a visit to the Math Center - 10 minutes
   - An assessment of your students' mathematical understanding using a concept map after the visit to the Math Center - 30 minutes

   b) The amount of time involved in your participation will be:
   Students:
   - One hour pre field trip
   - Two hour field trip
   - One hour post field trip
   - Total Time: 4 hours

Teacher:

- One hour pre field trip
- Two hour field trip
- One hour post field trip
- <u>Total Time: 4 hours</u>

In remuneration for your time, your class will receive free admission to The Metamo4ic Math Center. Please note this does not include transportation to or from the Math Center.

Approximately a total of 600 subjects will be involved in this research.

There are no anticipated risks associated with this research.

4. There are no direct benefits for you participating in this study. However, your participation will contribute to the knowledge about the potential benefit of utilizing informal science in instructional practices for mathematics and may help society.
5. Your participation is voluntary and you may choose not to participate in this research study or to withdraw your consent at any time. You may choose not to answer any questions that you do not want to answer. You will NOT be penalized in any way should you choose not to participate or to withdraw.
6. We will do everything we can to protect your privacy. As part of this effort, your identity will not be revealed in any publication or presentation that may result from this study and the information collected will remain in the possession of the investigator in a safe location.
7. If you have any questions or concerns regarding this study, or if any problems arise, you may call the Investigator, Vicki Adams (314) 954-8701 or the Supervising Faculty, Dr. William Emrick (636) 949-4771. You may also ask questions of or state concerns regarding your participation to the Lindenwood Institutional Review Board (IRB) through contacting Dr. Jann Weitzel, Vice President for Academic Affairs at 636-949-4846.

I have read this consent form and have been given the opportunity to ask questions. I will also be given a copy of this consent form for my records. I consent to my participation in the research described above.

____________________________________ ____________________________________

Participant's Signature Date Participant’s Printed Name

____________________________________ ____________________________________

Signature of Principal Investigator Date Investigator Printed Name

Appendix J

In-Service Teacher Permission Form for Study: Control Group

Lindenwood University

School of Education
209 S. Kingshighway
St. Charles, Missouri 63301

Informed Consent for Participation in Research Activities

Employment of an Informal Educational Mathematical Facility to Lower Math Anxiety and Improve Teacher and Student Attitudes towards Understanding Mathematics

Principal Investigator: Vicki Adams
Telephone: 314-954-8701 E-mail: vra705@lindenwood.edu

Participant ____________________________ Contact Info _________________________

1. You are invited to participate in a research study conducted by Vicki Adams under the guidance of Dr. William Emrick. The purpose of this research is to determine what a visitor gains from a visit to The Metamo4ic Math Center.

2. a) Your participation will involve
   - A pre-assessment of your attitudes towards math - 10 minutes
   - A pre-assessment of your students' attitudes toward math - 10 minutes
   - A pre-assessment of your students' mathematical understanding using a concept map - 30 minutes
   - A post assessment of your attitudes towards math - 15 minutes
   - A post assessment of your students' attitudes toward math - 15 minutes
   - A post assessment of your students' mathematical understanding using a concept map - 30 minutes

   b) The amount of time involved in your participation will be:
   Students:
   - One hour pre-study
   - One hour post study
   - <u>Total Time: 2 hours</u>

   Teacher:
   - One-half hour pre field trip
   - One-half hour post field trip

- <u>Total Time: 1 hour</u>

In remuneration for your time, your class will receive free admission to The Metamo4ic Math Center after the completion of the study. Please note this does not include transportation to or from the Math Center.

Approximately a total of 600 subjects will be involved in this research.

There are no anticipated risks associated with this research.

4. There are no direct benefits for you participating in this study. However, your participation will contribute to the knowledge about the potential benefit of utilizing informal science in instructional practices for mathematics and may help society.
5. Your participation is voluntary and you may choose not to participate in this research study or to withdraw your consent at any time. You may choose not to answer any questions that you do not want to answer. You will NOT be penalized in any way should you choose not to participate or to withdraw.

6. We will do everything we can to protect your privacy. As part of this effort, your identity will not be revealed in any publication or presentation that may result from this study and the information collected will remain in the possession of the investigator in a safe location.

7. If you have any questions or concerns regarding this study, or if any problems arise, you may call the Investigator, Vicki Adams (314) 954-8701 or the Supervising Faculty, Dr. William Emrick (636) 949-4771. You may also ask questions of or state concerns regarding your participation to the Lindenwood Institutional Review Board (IRB) through contacting Dr. Jann Weitzel, Vice President for Academic Affairs at 636-949-4846.

I have read this consent form and have been given the opportunity to ask questions. I will also be given a copy of this consent form for my records. I consent to my participation in the research described above.

Participant's Signature Date	Participant's Printed Name
Signature of Principal Investigator Date	Investigator Printed Name

Appendix K

Pre-Service Teacher Permission Form for Study: Treatment Group

Lindenwood University

School of Education
209 S. Kingshighway
St. Charles, Missouri 63301

Informed Consent for Participation in Research Activities

Employment of an Informal Educational Mathematical Facility to Lower Math Anxiety and Improve Teacher and Student Attitudes towards Understanding Mathematics

Principal Investigator: Vicki Adams
Telephone: 314-954-8701 E-mail: vra705@lindenwood.edu

Participant________________________________ Contact Info ______________________

1. You are invited to participate in a research study conducted by Vicki Adams under the guidance of Dr. William Emrick. The purpose of this research is to determine what a visitor gains from a visit to The Metamo4ic Math Center.

2. a) Your participation will involve
   - An assessment of your attitudes towards math before a visit to the Math Center - 10 minutes
   - An assessment of your mathematical understanding using a concept map before the visit to the Math Center - 30 minutes
   - You will experience a 2-hour visit @ the Math Center in Ferguson, Missouri
   - An assessment of your attitudes towards math after a visit to the Math Center - 10 minutes
   - An assessment of your mathematical understanding using a concept map after the visit to the Math Center - 30 minutes
   - Optional pre-visit and focus group interviews

   b) The amount of time involved in your participation will be:

   - One hour pre field trip
   - Two hour field trip
   - One hour post field trip

- Total Time: 4 hours

In remuneration for your time, you will receive free admission to The Metamo4ic Math Center. Please note this does not include transportation to or from the Math Center.

Approximately a total of 600 subjects will be involved in this research.

There are no anticipated risks associated with this research.

4. There are no direct benefits for you participating in this study. However, your participation will contribute to the knowledge about the potential benefit of utilizing informal science in instructional practices for mathematics and may help society.
5. Your participation is voluntary and you may choose not to participate in this research study or to withdraw your consent at any time. You may choose not to answer any questions that you do not want to answer. You will NOT be penalized in any way should you choose not to participate or to withdraw.

6. We will do everything we can to protect your privacy. As part of this effort, your identity will not be revealed in any publication or presentation that may result from this study and the information collected will remain in the possession of the investigator in a safe location.

7. If you have any questions or concerns regarding this study, or if any problems arise, you may call the Investigator, Vicki Adams (314) 954-8701 or the Supervising Faculty, Dr. William Emrick (636) 949-4771. You may also ask questions of or state concerns regarding your participation to the Lindenwood Institutional Review Board (IRB) through contacting Dr. Jann Weitzel, Vice President for Academic Affairs at 636-949-4846.

I have read this consent form and have been given the opportunity to ask questions. I will also be given a copy of this consent form for my records. I consent to my participation in the research described above.

________________________________ ________________________________

Participant's Signature Date Participant’s Printed Name

________________________________ ________________________________

Signature of Principal Investigator Date Investigator Printed Name

Appendix L

Pre-Service Teacher Permission Form for Study: Control Group

Lindenwood University

School of Education

209 S. Kingshighway
St. Charles, Missouri 63301

Informed Consent for Participation in Research Activities

Employment of an Informal Educational Mathematical Facility to Lower Math Anxiety and Improve Teacher and Student Attitudes towards Understanding Mathematics

Principal Investigator: Vicki Adams
Telephone: 314-954-8701 E-mail: vra705@lindenwood.edu

Participant________________________________ Contact Info ______________________

1. You are invited to participate in a research study conducted by Vicki Adams under the guidance of Dr. William Emrick. The purpose of this research is to determine what a visitor gains from a visit to The Metamo4ic Math Center.

2. a) Your participation will involve
   - An assessment of your attitudes - 10 minutes
   - An assessment of your mathematical understanding using a concept map - 30 minutes

- One hour pre-assessments
- One hour post-assessments
- <u>Total Time: 2 hours</u>

In remuneration for your time, you will receive free admission to The Metamo4ic Math Center after the study. Please note this does not include transportation to or from the Math Center.

Approximately a total of 600 subjects will be involved in this research.

There are no anticipated risks associated with this research.

4. There are no direct benefits for you participating in this study. However, your participation will contribute to the knowledge about the potential benefit of utilizing informal science in instructional practices for mathematics and may help society.
5. Your participation is voluntary and you may choose not to participate in this research study or to withdraw your consent at any time. You may choose not to answer any questions that you do not want to answer. You will NOT be penalized in any way should you choose not to participate or to withdraw.

6. We will do everything we can to protect your privacy. As part of this effort, your identity will not be revealed in any publication or presentation that may result from this study and the information collected will remain in the possession of the investigator in a safe location.

7. If you have any questions or concerns regarding this study, or if any problems arise, you may call the Investigator, Vicki Adams (314) 954-8701 or the Supervising Faculty, Dr. William Emrick (636) 949-4771. You may also ask questions of or state concerns regarding your participation to the Lindenwood Institutional Review Board (IRB) through contacting Dr. Jann Weitzel, Vice President for Academic Affairs at 636-949-4846.

I have read this consent form and have been given the opportunity to ask questions. I will also be given a copy of this consent form for my records. I consent to my participation in the research described above.

____________________________________ ____________________________________

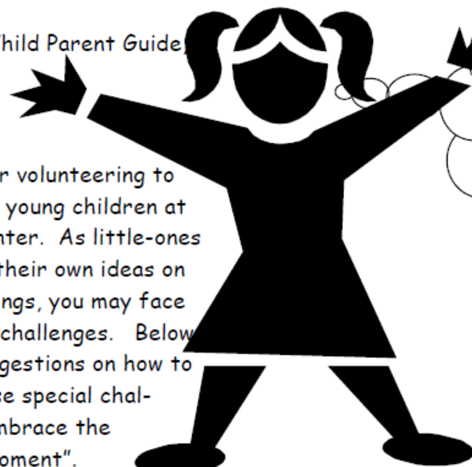
Participant's Signature Date | Participant's Printed Name

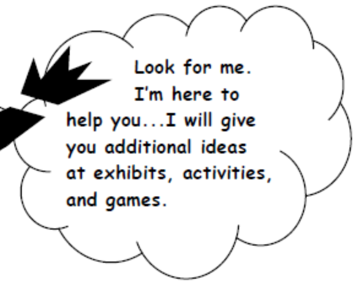
____________________________________ ____________________________________

Signature of Principal Investigator Date | Investigator Printed Name

Appendix M

Young Child Guide for Educators and Parents





Dear Young Child Parent Guide,

Thank you for volunteering to be a guide of young children at the Math Center. As little-ones usually have their own ideas on how to do things, you may face some special challenges. Below are some suggestions on how to react to these special challenges and embrace the "teachable moment".

Please feel free to ask for assistance from your teachers or from the Math Center Staff.

- If the children seem more involved with the math toys than the activity, give the children 2-3 minutes to play with the math toys and then direct their attention to the activity by saying something like, "I see you enjoy playing with ______. Listen to how you can use the _______." Then instruct and guide the children on the activity.
- Young children are trying to make sense of the world they live in. Allow the children to use the math tools/toys in their own creative ways as long as they are not putting things in their mouth or using something in an unsafe manner. However, always ask them to explain their mathematical thinking (patterns, shapes, numbers, etc). You might want to share yours with them too.
- The attention span of the young child is usually quite short. Please do not insist on the children on completing each exhibit or activity. Use your best judgment as to when it is time to move on.
- It's okay if the children don't get to each exhibit or activity.
- It's okay if the children complete or work with one exhibit or activity in each room as long as they are not "hogging" the activity and preventing other children who want to try the exhibit or activity from doing so.
- Always have the children clean-up and/or put back what they have used to where it belongs before moving to the next exhibit or activity.
- You are the guide. The more willing and excited you are to play with the children and the exhibits and activities, the more fun and learning there will be!

Appendix N

Directions to the Math Center

Directions
The Metamo4ic Math Center, 333 N. Florissant Rd., Ferguson, MO 63135, 314-807-3290

Print
Back To Map

From Highway 270(E):

- Head south (turn right) on Florissant Road (This exit is labeled New Florissant Road)
- You will pass January Wabash Park on your right (approx 2-3 miles)
- The entrance for the church and math center is the first turn on the right after January Avenue
- Look for the Metamo4ic Math Center sign under the church's sign
- Head towards the back of the church and look for the Metamo4ic Math Center sign by the entrance
- Follow the stairs to the top level

School buses, to de-board the students on the right side of the bus, pass the church and turn right on Blackburn (just past the church and before Kentucky Fried Chicken). Follow Blackburn to the very rear parking lot of the church and turn right into the parking lot. Follow the parking lot around the back of the church to the north side of the church. Watch for the Metamo4ic Math Center sign. Park in the parking lot nearest to January Wabash Park

From Highway 70:

- Head north on Florissant Road
- Make sure you are in the left lane before you cross Airport/Hereford Road
- Turn left at the second entrance to The First Baptist Church of Ferguson
- Look for the Metamo4ic Math Center sign under the church's sign
- Head towards the back of the church and look for the Metamo4ic Math Center sign by the entrance
- Follow the stairs to the top level

School buses, to de-board the students on the right side of the bus, do not pass the church but turn left on Blackburn (just before the church and just past Kentucky Fried Chicken). Follow Blackburn to the very rear parking lot of the church and turn right into the parking lot. Follow the parking lot around the back of the church to the north side of the church. Watch for the Metamo4ic Math Center sign. Park in the parking lot nearest to January Wabash Park

Appendix O

Site Speech

IT RAPS RAPPS D^3 CARGO

Introduction - Welcome

My name is Ms. Adams
This is Mrs. Stewart (or Miss Paula)

Thank you to FBCF for donating the space to the Math Center

Right Road

75% High School students have math anxiety
90% of the jobs college graduates are getting have high math demands

Attitude

Practice

Albert Pujols is a great baseball player because he has a positive attitude and practices

Stick-to-it-tive-ness

Tom Edison stuck to it over 200 times…otherwise you would be sitting in the dark

Rooms are color-coded

Red tape, Orange tape, Yellow tape, Green tape

Attention

If we say "Marco", you say…"Polo"
Two minute warning

Procedure

When you rotate, enter the room and sit down
Except Yellow Room gather around ProBot Table
Adult Guides will get kids started - don't wait on us

Pennants

Starting points
No more than 4 students at one exhibit/activity

Safety

Giant pick-up sticks are not swords
Golf clubs are not baseball bats

D^3

Directions - read them
Duty - clean-up
Differentiation

Green - No experience
Blue - Some experience
Black – Experienced

Red - Challenge

Customized Activities

Mural
Art Projects
Data/Question of the Day

And

Restrooms

Go Figure - boards to do calculations hang on the door knobs and up front in the hall

O- Hand sanitizer

Appendix P

Math Anxiety Scale – Revised (MAS-R)

(MAS-R) Math Anxiety Scale

1. I find math interesting

**Strongly……........Agree…………..Neutral…..……...Disagree………..…Strongly
Agree Disagree**

2. I get uptight during math tests

**Strongly……........Agree…………..Neutral…..……...Disagree………..…Strongly
Agree Disagree**

3. I think I will use math in the future

**Strongly……........Agree…………..Neutral…..……...Disagree………..…Strongly
Agree Disagree**

4. My mind goes blank and I am unable to think clearly when doing my math test

**Strongly……........Agree…………..Neutral…..……...Disagree………..…Strongly
Agree Disagree**

5. Math relates to my life

**Strongly……........Agree…………..Neutral…..……...Disagree………..…Strongly
Agree Disagree**

6. I worry about my ability to solve math problems

**Strongly……........Agree…………..Neutral…..……...Disagree………..…Strongly
Agree Disagree**

7. I get a sinking feeling when I try to do math problems

**Strongly……........Agree…………..Neutral…..……...Disagree………..…Strongly
Agree Disagree**

8. I find math challenging

**Strongly……........Agree…………..Neutral…..……...Disagree………..…Strongly
Agree Disagree**

9. Mathematics makes me feel nervous

**Strongly……........Agree…………..Neutral…..……...Disagree………..…Strongly
Agree Disagree**

10. I would like to take more math classes

Strongly……........Agree…………..Neutral…..……...Disagree………..…Strongly
Agree Disagree

11. Mathematics makes me feel uneasy

Strongly……........Agree…………..Neutral…..……...Disagree………..…Strongly
Agree Disagree

12. Math is one of my favorite subjects

Strongly……........Agree…………..Neutral…..……...Disagree………..…Strongly
Agree Disagree

13. I enjoy learning with mathematics

Strongly……........Agree…………..Neutral…..……...Disagree………..…Strongly
Agree Disagree

14. Mathematics makes me feel confused

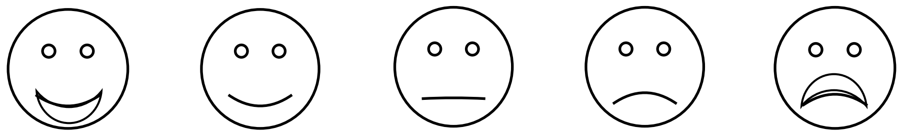
Strongly……........Agree…………..Neutral…..……...Disagree………..…Strongly
Agree Disagree

Appendix Q

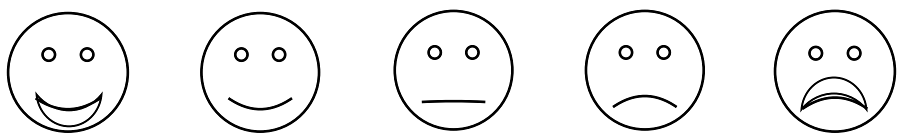
Math Anxiety Scale (MAS-R) – Revised (First Grade)

Adapted MAS-R (Math Anxiety Scale Revised) for grades 1 and 2

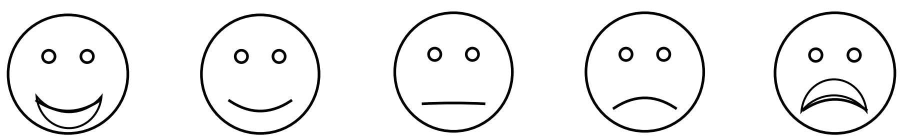
1. Math is fun.



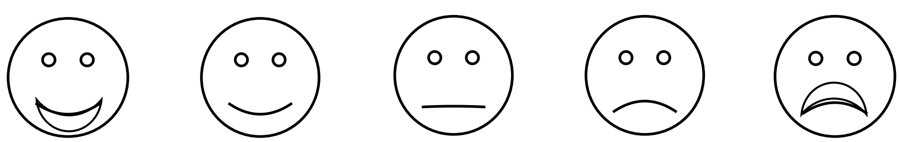
2. I worry about how good I am at math on math tests.



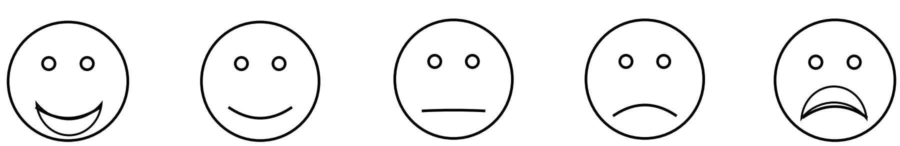
3. I will use math when I get older.



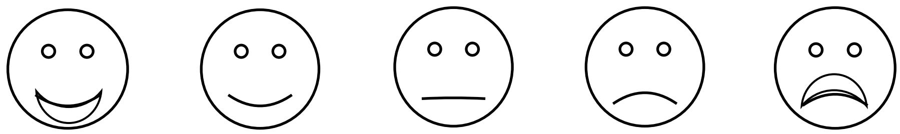
4. I forget what I have learned when I take a math test.



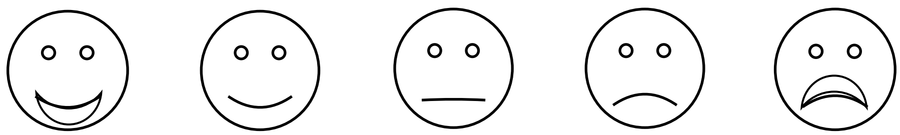
5. I use math when I am not at school.



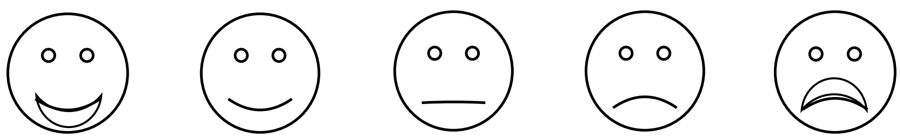
6. I worry about how good I can do math problems.



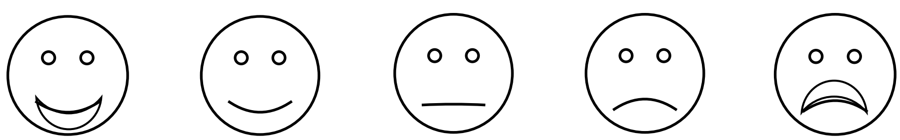
7. I do not like doing math problems.



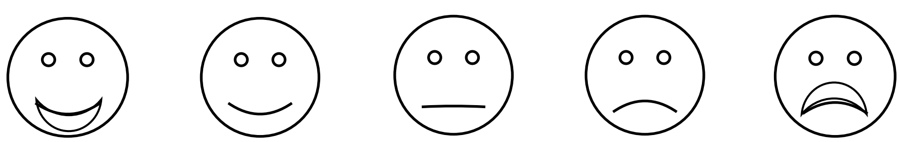
8. I think math is hard.



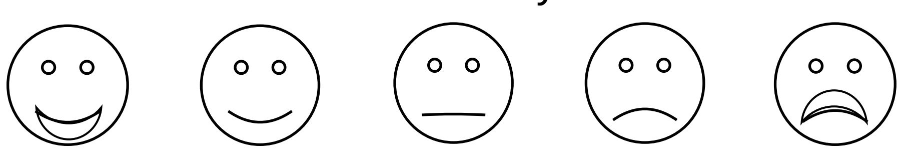
9. Math makes me feel sad.



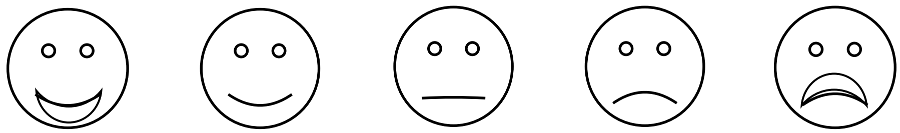
10. I want to spend more time in school doing math.



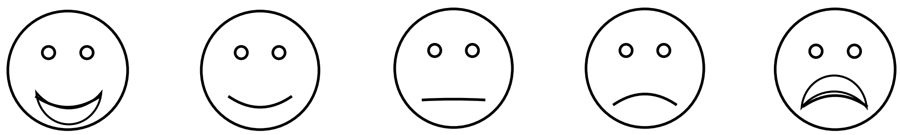
11. Math makes me feel uneasy.



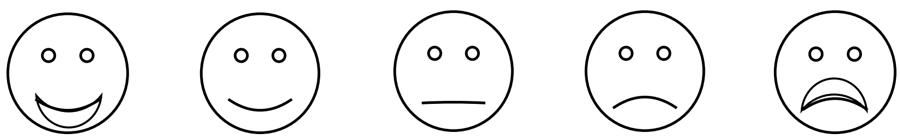
12. I like to do math in school.



13. I like to learn with math.



14. Math makes me feel lost.



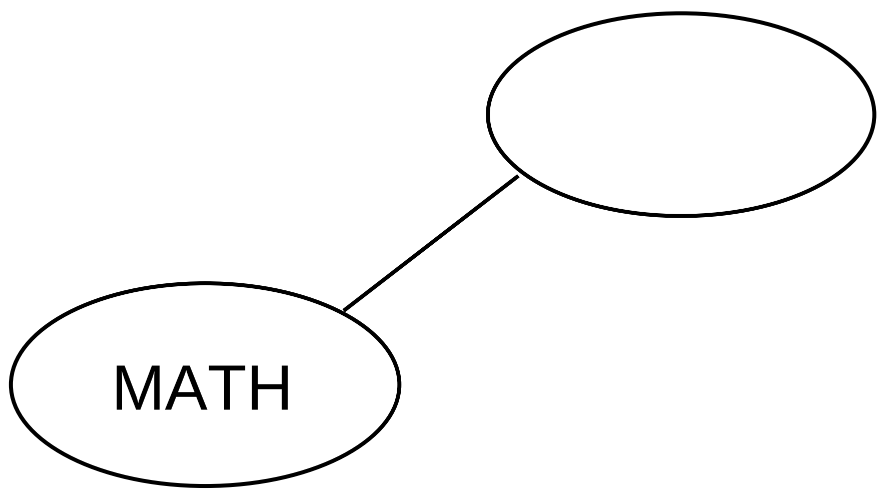
Appendix R

Knowledge Concept Map

What is Math?

Number ________________________ Pre Visit / Post Visit

Date ______ / ______ / ______



Appendix S

In-Service and Pre-Service Teacher Interviews

Interview Questions for Teachers:

Pre Visit

1. How did you use the organizational materials to plan the fieldtrip experience to the Math Center?
2. How did you select the activities to customize the visit to the Math Center for your students?
3. How have you prepared your students for the visit to the Math Center?
4. What comments or thoughts have your students expressed about the visit to the Math Center?
5. How can you describe your:
    a. attitude(s) towards learning and teaching of mathematics?
    b. anxieties towards learning and teaching of mathematics?
    c. proficiency with mathematics?
6. How do you characterize the state of mathematics instruction in your classroom?

Post Visit

1. What comments or thoughts have your students expressed since the visit to the Math Center?
2. How have you utilized the fieldtrip visit in mathematical instruction?
3. What exhibits specifically met the objectives of math instruction in your classroom?
    a. Did the exhibits align with the curriculum in your school and/or district?
4. What impact did the giant-size exhibits have on your students?
5. What impact did the parent guides have on the visit for your students?
6. What changes in attitude, anxiety, and/or proficiency levels with mathematics have you or your students experienced since the visit to the Math Center?
7. What changes have occurred in math instruction in your classroom since the visit to the Math Center?

Interview Questions for Pre-service Teachers

1. What expectations do you have from a visit to the Math Center?
2. What do you think actually occurs at the Math Center?
3. How can you describe your:
    a. attitude(s) towards learning and teaching of mathematics?
    b. anxieties towards learning and teaching of mathematics?
    c. proficiency with mathematics?

Focus Group Questions for Teachers:

1. How does the Math Center provide learning opportunities for both students and teachers?
2. How did the visit to the Math Center affect your instruction of mathematics?
3. How do you plan to use this experience in your classroom?
4. What is the importance of the giant size exhibits?
5. How can the Math Center provide access, motivation, and inspiration for students to feel successful at mathematics?
6. How can the Math Center be improved?

Focus Group Questions for Lindenwood Pre-service Teachers

1. How does the Math Center provide learning opportunities for both students and teachers?
2. How did the experience at the Math Center affect your understanding of math instruction?
3. How do you plan to use this experience in your future classroom?
4. What is the importance of the giant-size exhibits?
5. How can the Math Center provide access, motivation, and inspiration for students to feel successful at mathematics?
6. How can the Math Center be improved?

Appendix T

Observation Form for Field Trips

Visitor Behavior Observation Sheet

Date ____/____/____ **Room** ________________________
Observer ________________________________

Numbers represent students
CODE:
M = Adult male parent guide
F = Adult female parent guide
T = Teacher
OS = Other Staff
G = Girl
B = Boy

INTERACTION:
Together do not interact # — #
One watchers another (#)
Interact together # ⟷ #

Exhibits

S = Measure Treasure Scale
H = Hotels
G = Geoboard
B = Bowling
TP = Tangram Puzzle
C = Chinese Checkers

Ignore	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Attend	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Engage	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Use Successfully	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

Ignore	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Attend	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Engage	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Use Successfully	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

Comments: ____

Appendix U

Data Checklist for In-Service Teachers

Data Checklist
Treatment Group

Thank you for volunteering to participate in this study! The list may look overwhelming, but indicates all the dates and details to help us communicate and work together through this process. My goal is to make this as uncomplicated and "painless" as possible, so please contact me if I can be of assistance. I can be reached at 314-954-8701 or vradams@sbcglobal.net.

Copies of all forms and directions on completion will be provided to you.

- ☐ Sign Teacher Adult Consent Form
- ☐ Sent home Parent -Student Consent Form
- ☐ Called or emailed as soon as all forms are returned preferably by ____/____/2011
- ☐ Emailed my class list
- ☐ Reviewed Pre-trip information sent via email from the Math Center
- ☐ Set up time for phone or in person interview at your school one-week before visit to Math Center. Time scheduled for interview:
    - Phone
    - School
    - Date ____/____/2011
    - Time __:__ AM/PM
- ☐ Interviewed before visit
- ☐ Reviewed instructions for administering Concept Knowledge Map (allow 15-30 minutes)
- ☐ Reviewed Instructions for administering MAS-R survey (allow 5-10 minutes)
- ☐ Administered Concept Knowledge Map one-week before visit on ____/____/2011
    - class
    - myself
- ☐ Administered MAS-R survey one-week before visit on ____/____/2011
    - class
    - myself
- ☐ Math Center collected Concept Knowledge Maps and surveys on ____/____/2011
- ☐ Visited Math Center
- ☐ Time set-up for post field trip interview
    - Phone
    - School
    - Date ____/____/2011
    - Time __:__ AM/PM
- ☐ Interviewed after visit
- ☐ Administered Concept Knowledge Map one-week post visit on ____/____/2011
    - class
    - myself
- ☐ Administered MAS-R survey one-week post visit on ____/____/2011
    - class

- myself

- ☐ Math Center collected Concept Knowledge Maps and surveys on ____/____/2011
- ☐ Time set-up for post field trip interview
  - Phone
  - School
  - Date ____/____/2011
  - Time __:__ AM/PM
- ☐ Administered Concept Knowledge Map one-month post visit on ____/____/2011
  - class
  - myself
- ☐ Administered MAS-R survey one-month post visit on ____/____/2011
  - class
  - myself
- ☐ Math Center collected Concept Knowledge Maps and surveys on ____/____/2011
- ☐ Interviewed again one month after visit
- ☐ Participated in Focus Group Interview: Tentatively set for Saturday, June 4, 2011

Thank you again!

Appendix V

In-Service Teacher Instructions for the MAS-R and Knowledge Concept Map

Concept Knowledge Map - What is Math?

Instructions - Administering Pre and Post Trip Assessments

1. Please no names on the paper.
2. Please refer to your class list that you provided and give each student the numbered paper that has been assigned to him or her.
3. Use the PowerPoint Presentation to demonstrate to your students how to complete the Concept Knowledge.
4. Read the directions provided to the students.
5. Tell the students that there is no one correct way to make their map, they cannot be wrong, their maps will not be graded, and whatever they think/know about math would be the best way to complete the map.

Grades 1 and 2

Notes to guide you through the PowerPoint Presentation for the students:

Slide 1 - No Notes

Slide 2 - Please eliminate the linking words for your students. Say: This concept map tells about grass. Look at this arrow that points to "Green". Look at this arrow that points to "Brown". Green and brown talk about grass. You are going to make your own concept map.

Slide 3 - No Notes

Slide 4 - No Notes

Slide 5 - No Notes

Slide 6 - Say: Use your own words and connect them with lines to talk about, "What is math?" Once again, you are to use your own words and lines to tell about the main points of math.

Grades 3 - 5

Notes to guide you through the PowerPoint Presentation for the students:

Slide 1 - No Notes

Slide 2 - Say: This concept map tells about grass. Look at this arrow that points to "Green". How are grass and green connected? (Yes, they are connected with a linking word –"grows") Look at this arrow that points to "Brown". How are grass and brown connected? (Yes, they are connected with the linking words –"dries up and becomes") You are going to make your own concept map.

Slide 3 - No Notes

Slide 4 - No Notes

Slide 5 - No Notes

Slide 6 - Use your own words and connect them with lines with linking words to talk about, "What is math?" Once again, you are to use your own words and lines with linking words to tell about the main points of math.
Do not put your name on the paper.
If students need a model to be displayed to assist them in their design when making their maps, display slide 2, "What is a Concept Map?"

Mathematical Anxiety Scale - Revised (MAS-R)

Instructions - Administering Pre and Post Trip Assessments

Grades 1 and 2

1. Please no names on the paper.
2. Please refer to your class list that you provided and give each student the numbered paper that has been assigned to him or her.
3. Read the directions provided to the students.
4. Students should color-in the face that best describes the way they feel about each statement (sentence). A happy face is the same as "Strongly Agree" while a sad face is the same as "Strongly Disagree".
5. It is permissible to read each statement to your students and indicate (instruct) students to fill in the very happy face if they feel strongly in a good way about the statement (sentence), all the way to the very sad face should that be the best way to meet the needs of your students.
   a. Example for 1 - Aloud read: Math is fun. If you feel very very happy about math fill in the happy face with the big smile. If you feel happy about math, fill in the happy face. If you feel not happy but not sad/mad, fill in the face with the straight smile. If you feel sort of sad/mad, fill in the sad/mad face, and if the sentence makes you really sad/mad, fill in the very unhappy face.
6. Ask your students to be honest as possible about the way they feel.
7. Remind your students that this is to help someone else learn about teaching mathematics.

Grades 3 - 5

1. Please no names on the paper.
2. Please refer to your class list that you provided and give each student the numbered paper that has been assigned to him or her.
3. Read the directions provided to the students.
4. Students should circle the words about the way they feel about each statement (sentence) selecting from Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree.
5. It is permissible to read each statement to your students and indicate (instruct) students to circle the words they about the statement (sentence).
   a. Example for 1 - Aloud read: I find math interesting. If you feel that math is very interesting then circle Strongly Agree. If you find about math interesting, circle Agree. If you feel nothing one way or the other, circle Neutral. If you feel math is somewhat not interesting, circle Disagree, and if you think math is really not interesting, then circle Strongly Disagree.
6. Ask your students to be honest as possible about the way they feel.
7. Remind your students that this is to help someone else learn about teaching mathematics and how people learn mathematics.

Appendix W

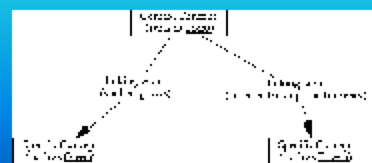
Instructions Provided to the In-Service Teachers for the Knowledge Concept Map

How to Make the Concept Map

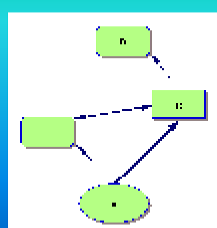
Employment of an Informal Educational Mathematical Facility to Improve Teacher and Student Anxieties, Attitudes, and Understanding Towards Teaching and Learning of Mathematics

What is a Concept Map?

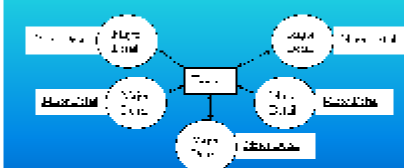
- A visual representation that tells what you know about a topic or concept.



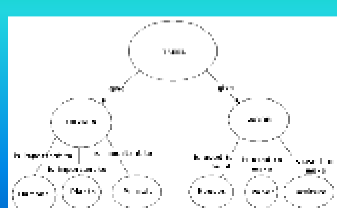
Concept maps can look like this



Or like this…



Or maybe like this…



What is Math?

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Vitae

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