The Effects of Mental Abacus Instruction on First and 2nd Grade Students' Math Assessment Scores in a Small Northeastern US State

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ABSTRACT

The abacus is a mathematical tool used to aid in calculations frequently utilized in ancient civilizations. In recent years, there has been an increase in the use of this apparatus in countries around the world. With the help of the physical tool, a mental image is developed, known as the Mental Abacus (MA). This technique of visualizing the actual physical abacus solves mathematical problems. Frank and Barner (2016) tested whether MA (a) improves arithmetic performance relative to a standard math curriculum and (b) leads to changes in spatial working memory, as claimed by several recent reports. Frank and Barner’s research indicated that mental abacus can provide positive gains in math for students who master the technique. This researcher expanded the study by examining the variables of gender, grade level, and standardized assessment. After a close analysis of the data, there was no statistically significant relationship between the utilization of the mental abacus and performance on memory tasks. It was found that age or grade level performance was affected by the use of the abacus. There was also no statistically significant relationship between the use of the mental abacus and the outcome of students’ standardized test scores.

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The completion of this dissertation is a testament of the resilient spirit instilled in me by my mother, Benda T. Williams. Mom, while you did not live long enough to witness this moment, it is finished. I did it.

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To God be the glory, great things God has done!

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CHAPTER I

INTRODUCTION

Think back to your first experience with basic mathematical computation like multiplication, division, addition, and subtraction. Many children utilized the use of fingers and the hand to help them master the basics of the subject. As children mature and gain confidence in mastering mathematical concepts, the expectation in this subject area is for them to move from the concrete use of fingers and hands to a more abstract means of solving math problems. Math and mathematical concepts may pose some difficulty for students if there is a rapid attempt to move from the concrete to the abstract. The use of manipulatives is encouraged to help students with this transition. One such apparatus is called an abacus. An abacus is a manipulative utilized in math to calculate numbers through beads used as counters. This tool was utilized at a North Jersey Elementary school to help increase the math capacity of students.

Math achievement continues to be one of the most widely studied phenomena in the education field. National and international studies have been conducted. The results of most of the studies indicate that the academic performance of students in the United States does not measure up to the educational level of students around the world (DeSilver, 2015). Educators throughout the United States continue to struggle with the problem of how to engage students in math across the nation. As a country, we struggle to compete mathematically even against some developing countries. Remembering A Nation at Risk recorded that the state of our country is in jeopardy educationally (National Commission on Excellence Revisited, 2018). The research indicated that the United States “never placed first or second" and often ranked “last seven times.” In 2016, another international study, A World of Difference, looked at how students from different countries fared against each other. China was ranked number one in the study, and the United States was last (PISA, 2016).

The International Association for the Evaluation of Educational Achievement (IEA) conducted the Third International Mathematics and Science Study (TIMSS). At the time, it was "[t]he largest and most ambitious study of educational achievement ever undertaken" (IEA, 1996, p. 1). The result demonstrated that the United States did not measure up to other industrialized nations in the mathematical achievement of their students. William Schmidt, the National Research Coordinator for the TIMSS research project records:

A significant disparity in the student achievement in the United States in comparison with the student performance in other countries includes the following factors:

Algebra and geometry are studied by most 8th-graders around the world, including Japan and Germany. However, in the United States, these subjects are reserved for students in higher-level classes in which, at most, 13% of our students are enrolled.

- U.S. mathematics teachers' typical goal is to teach students how to do something. In contrast, the goal of Japanese teachers is to help their students understand mathematical concepts.
- Japanese teachers widely practice what U.S. mathematics reformers recommend. Most U.S. teachers report that they are familiar with reform recommendations, but only a few have begun to apply these reforms in a meaningful way in their classrooms". (NCTM 2016).

Teachers and other educators in the U. S agreed and engaged in the "Math Wars."Educators, parents, the U.S. Department of Education, university professors, mathematicians, and other concerned community members contested the mindset of teaching students how to perform mathematical computations instead of understanding mathematical concepts (Klein, 2003). The struggle between content and pedagogy was a consistent topic amongst all parties. What to teach and how to teach math was a major conflict. The Department of Education has conducted major overhauls in the mathematics curriculum since the 1990s. Based on the evidence provided, it is evident that our country has failed to find a solution to the low performance of American students in mathematics in comparison to other nations. Since our country continues to lag in math education, it is clear that some adjustment in the curriculum and pedagogy is required immediately. In response to the need, the national standards were adopted across the country during the 1990s to align the mathematical program for students and provide some systemic structure from one classroom to another. The standards provided clarity and a more focused curriculum. The standards also prompted math educators to address conceptual understanding and stress the presentation of the material. New Jersey adopted the national standards and has made and followed through on a commitment to update the standards every 5 years to recalibrate the mathematical system in the United States (New Jersey Department of Education [NJDOE], 2020).

The Common Core State Standards for Mathematics (now, the New Jersey Student Learning Standards) are organized by grades, ranging from K-8, and were adopted by the State of New Jersey and 42 other states. The standards were adopted to bring uniformity from state to state. To accomplish this mission, researchers of Mathematics, State Departments of Education, scholars, assessment developers, professional organizations, educators, parents, students, and members of the public got together. They looked at standards from across the nation and from other countries known to perform well in math. After analyzing the data, several mathematical concepts and a list of skills students needed to acquire and master were agreed upon and subsequently formalized and adopted. The NJ Common Core, now the NJ Student Learning Standards skills for 1st and 2nd grade pertaining to mathematics, are briefly described next.

According to the standards, in Grade 1, instructional time should focus on four critical areas: (a) developing understanding of addition, subtraction, and the strategies for addition and subtraction within 20; (b) developing the understanding of whole number relationships and place value, including grouping in tens and ones; (c) developing the understanding of linear measurement and measuring lengths as iterating length units; and (d) reasoning about attributes of, and composing and decomposing geometric shapes (Ginsburg & Leinwand, 2009; Schmidt et al., 2002).

In Grade 2, instructional time should focus on four critical areas: (a) extending the understanding of base-ten notation; (b) building fluency with addition and subtraction; (c) using standard units of measure; and (d) describing and analyzing shapes (Ginsburg & Leinwand, 2009; Schmidt et al., 2002).

Problem Statement

For more than a decade, research studies of mathematics education in high-performing countries have concluded that mathematics education in the United States must become substantially more focused and coherent to improve mathematics achievement in this country. The mathematics standards are designed to address the problem of a curriculum that is "a mile wide and an inch deep” (NJDOE, 2016). In addition, the NJ Department of Education and the National Council of Teachers of Mathematics recognize the need to place particular attention on the components of the math curriculum (NCTM 2016; NJDOE, 2016).

Greater emphasis has to be placed on the mental computation portion of the curriculum. Both the NJ Department of Education and the National Council of Teachers of Mathematics recognize that part of the problem in the United States is our approach to teaching mathematics which has been by relying on the method of routine operations involving numbers. This abstract learning style does not teach fundamental mathematical concepts. Without this basic concrete understanding, students find it challenging to transfer the learning from the concrete model to the abstract idea because of the lack of modeling. To bring uniformity from state to state, the approach should include "Mathematics instruction that typically begins by introducing children to a system of numerals and a set of arithmetic routines that operate on these numerals" (NJDOE, 2016).

For many children around the world, early math lessons are supplemented by the use of an abacus, a physical manipulative designed for representing exact quantities via the positions of counters (2016). The abacus can be traced as far back as 1200 AD or earlier (Menninger, 1968). In addition, a technique known as Mental Abacus (MA) is utilized in countries like India, China, Japan, Singapore, and South Korea. Once exposed to the physical abacus, students begin to visualize the abacus mentally. Thus, the term MA has been coined to refer to this concept.

Mental computation promotes flexible thinking skills and number sense (Reys, 1985; Reys & Barger, 1994). In this concept, children mentally visualize the physical abacus and utilize the device mentally to rapidly and accurately solve math calculations. As part of the curriculum, this technique has had success in elementary mathematics classrooms in Asia and directly affects students' spatial and concentration skills (Hatano et al., 1987; Stigler et al., 1986). Considering the demands of the New Jersey Student Learning Standards and the desire for students to go from rote memorization in mathematics to an in-depth application of major concepts, the adoption of MA could contribute to students increasing their basic math computation and problem-solving skills. Furthermore, it is noted in MA studies that there are significant advantages gained by exposing students to MA at an early age to acquire the skills of using an abacus and receive the benefits of MA in their formative years. Students who master the concept of the abacus master the art of computation and thus become more comfortable with math and math concepts (Bonner et al., 2016).

The study made it imperative to differentiate between using a concrete physical abacus and transferring the physical abacus image to the brain to utilize the Mental Abacus (MA). Mental Abacus instruction enables students to visualize the actual abacus in their minds. Consequently, they can perform simple, age-appropriate computations of addition, subtraction, multiplication, and division in their heads. In addition, the students often move their hands to simulate the movements of the beads on the abacus; the motion helps them perform the computation task with confidence and accuracy. Students' basic addition skills utilizing the abacus tool are outlined as necessary for 1st and 2nd graders in the state mathematics standards.

Theoretical Framework

The work of Vygotsky has been utilized as the basis for numerous research and theory pertaining to the development of children and the social Development theory (Daniels, 2016). Vygotsky's theories emphasize how important social interaction is in how children learn and develop. Vygotsky's work is pertinent to this study because of his thoughts around "intellectual adaptation-that allows children to use the basic mental functions more effectively/adaptively, and these are culturally determined" (Daniels, 2016). His work around how society shapes the development of children's learning becomes crucial in the work of the abacus/mental abacus. His foundational work creates a pathway for exploration into how the mental abacus impacts students' learning.

Purpose of the Study

The purpose of the study is to determine the effects of Physical Abacus training on the Mental Abacus on 1st- and 2nd-grade students' Star standardized math assessment and to examine whether there are any differences according to gender or grade levels in a small suburban district in New Jersey. The research questions for this study were the following:

1. Does implementing the abacus curriculum improve the overall mathematics achievement of 1st and 2nd graders as measured by the STAR assessment diagnostic achievement test?

   Null Hypotheses:

   a) There is no statistically significant difference between the overall pre- and post-mean scores for 1st graders exposed to the abacus versus those who were not.

   b) There is no statistically significant difference between the overall pre- and post-mean scores for 2nd graders exposed to the abacus versus those who were not.

2. How do physical abacus and mental abacus use affect the assessment scores of 1st graders versus 2nd graders?

   Null Hypotheses

   a) There is no statistically significant difference between the pre- and post-growth scores for 1st and 2nd graders.

3. Is there a statistically significant difference in the growth in mathematics test scores of students who underwent the abacus training compared to students in the control group, and does grade level affect the outcomes?

Null Hypotheses:

a) There is not an interaction between grade level and participation in abacus training.

If the null hypothesis is not rejected:

b) There is no difference in the growth for the different grade level STARS scores and

c) There is no difference for students in abacus and control groups.

3. Does the mental abacus improve students' working memory, and does grade level affect the outcome?

Null Hypotheses:

a) There is not an interaction between grade level and participation in abacus training on working memory.

If the null hypothesis is not rejected:

b) There is no difference in the growth for the different grade level scores and

c) There is no difference for students in abacus and control groups.

5. Is there a statistically significant difference in growth scores of male students versus female students who were exposed to physical/mental abacus training?

Null Hypotheses:

a) There is no significant difference in male students' versus female students' math growth scores exposed to the physical/mental abacus training.

Significance of the Study

The U.S. has lagged behind many countries in the world when it comes to math performance. Emphasis is placed on how students perform mathematically, which is used as an indicator of future success (Wang, 2020). The United States has adopted some learning standards to help support mathematical reform. The abacus/mental abacus technique could be another means of accelerating the mathematical performance of American students. This study explored the effects the abacus/mental abacus had on students' standardized test scores based on the students' gender, grade level, and memory.

Limitations

The variables examined in this study yielded valuable information; however, there were some noted limitations. Some observed limitations are outlined here. Past studies conducted on the use of the abacus and mental abacus with elementary school children have been longitudinal, spanning over 2 years. This abacus study was performed over 1 year. The students were not exposed to the abacus/mental abacus curriculum daily. In essence, the students were not exposed to a full school year of the material. The abacus/mental abacus was taught several days of the week for half of a 90-minute class. The material was also taught in conjunction with the regular math curriculum (Singapore Math). The lack of consistency and exposure to the abacus/mental abacus practices could have impacted the study results.

The teacher is an integral part of the pedagogy. Knowing and feeling comfortable teaching the content are essential aspects of delivering instruction. The teachers in the study were often taught the material the week they needed to teach it to the students. Their level of familiarity with the content could have been a factor in the outcome of the study. These were some of the limitations.

Definitions:

Abacus: The abacus is a manipulative utilized in math to calculate numbers through beads used as counters.

Mental Abacus: An important acquired technique that enables individuals to perform mathematical computations using the image of an abacus mentally.

NJ Common Core/NJ Learning Standards: Written descriptions of what students are expected to know and be able to do at a specific stage of their education within a particular grade level and/or age.

Manipulatives: Are any concrete objects that allow students to explore an idea in an active, hands-on approach.

CHAPTER 2

LITERATURE REVIEW

Introduction

The purpose of this study is to examine the effects of the mental abacus on students' math assessment scores and students' working memory. This chapter evaluates different research and their outcomes related to the abacus and the mental abacus. I looked at the origin of the abacus and explained how the physical abacus is used to develop the skill of transference from the physical apparatus to a mental or envisioned tool. The research examined work by researchers whose focus was on the cognitive development of children, which relates to the development question in the study, which looked if there were any differences in the students' performances based on their age and gender. Researchers including Barnrer and Frank, and Stigler, leaders on the abacus and mental abacus, have also made major contributions to the research topic. This chapter reviews and compares their work to evaluate any significant differences in students' math assessment performances.

Abacus

The abacus is a manipulative utilized in math to calculate numbers through beads used as counters. The device pictured in Figure1 is widely used in European countries. The Mathematical Association gives a brief account of what an abacus is:

> The principles of abacus arithmetic were first developed in the Middle East over 5000 years ago by the Sumerian civilization. This civilization was probably the first to develop the subject of mathematics and their sexagesimal number system, which used the base 60 and 16; this system is still used to measure time. In its earliest form, the abacus was probably a sand table with pebbles being used as

counters. From this form, it evolved to its modern design with beads moving on rods. This version dates from the Greek and Roman civilizations. The abacus in its various forms continued to be used in Western Europe until the Middle Ages. (Maxwell, 1981, pp. 2–3)

There are many versions of the abacus, and different countries utilize different versions of this counting device. The Chinese abacus, known as the suanpan, was first described in a book written by Xu Yue of the Eastern Han Dynasty, namely Supplementary Notes on the Art of Figures written about 190 A.D. (Kim, 2016). The modern suanpan has 5 beads, including one upper bead and 4 bottom beads. The beads are colored to indicate position, and there is a clear-all button (Kim, 2016).

Figure 1. Image of the Soroban Abacus

According to Kim, the Korean abacus is called jupan, and was imported from the Chinese around 1592. Until 1900, the Chinese abacus had five bottom beads plus two upper beads on each rod, and only merchants used their calculation method. After the Cho-Seon Abacus Association was established in 1920, the Japanese simplified the abacus, and the Soroban abacus was introduced to Korea, becoming the current Korean abacus. From 1932 on, the current Korean abacus with four plus one beads was accepted (Kim, 2016). The Soroban, pictured above, is centered on a base-ten counting system. The apparatus is framed and uses the four beads on the bottom and the one on the top to represent numbers. Each column represents a specific value (ones, tens, hundreds, thousands, etc.). The starting point on the manipulative is marked so that the individual knows where to begin. Each column represents a base-ten numeral. For example, the number 561 would be represented on three abacus columns using beads next to each other.

The diagram, pictured below, is divided into two domains, the upper and lower domain. Each bead is counted as five units in the upper section of the abacus when it is closest to the bar that separates the two domains. So, in the ones' column, the top bead would be valued as 5, in the tens' column, the top bead would be 50, and in the hundreds' column, the top bead would be 500, etc.). When the bead is up, it is considered neutral and counted as 0 or nothing. All upper beads are up and lower beads down.) When they are in the up position, the beads below the bar are counted one time, whatever the value of that column is. So, for ones, it would be ones, for the tens, it would be tens, and for the one hundreds, the same (see Figure 2).

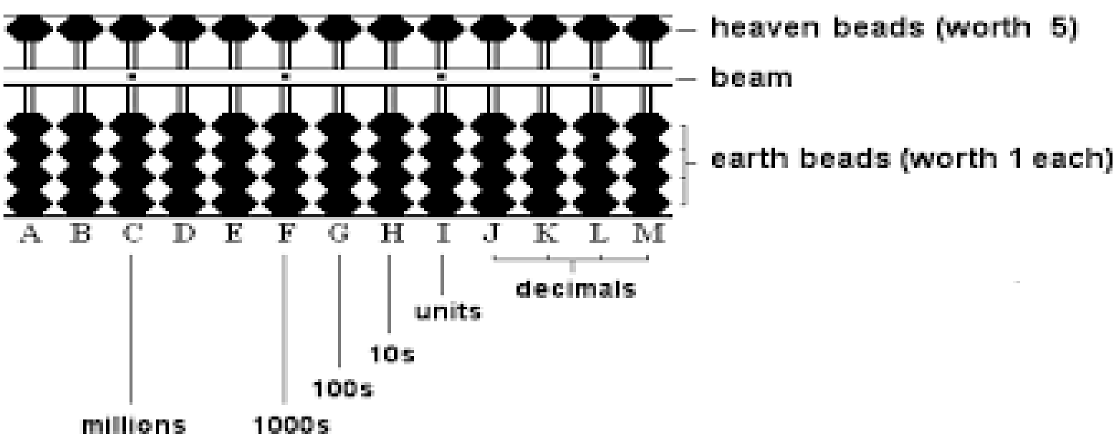

Figure 2. Place values.

By maneuvering the beads, it is possible to combine them with the top bead in the ones column pushed down to the dividing line and the four lower beads pushed up; this combination represents the number 9. Three would be demonstrated with the upper bead pushed up and the lower beads pushed up towards the dividing bar (Figure 3).

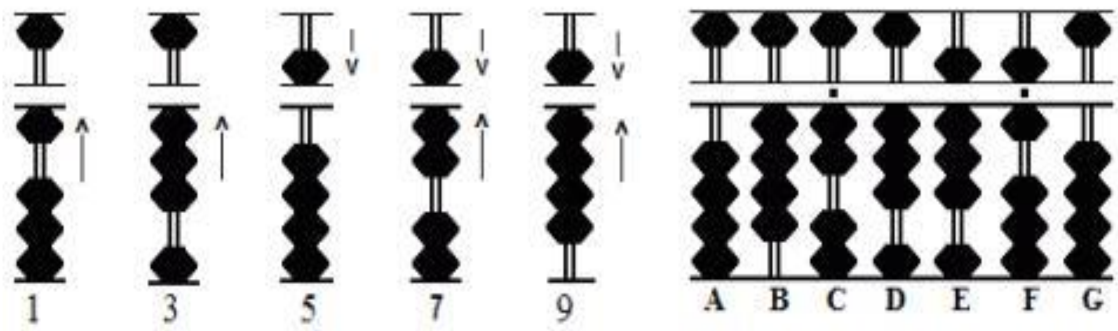

Fig: 6

Figure 3. Google image.

The students have to master the movements of the beads and automatically consider the complements of numbers to maneuver the beads to compute basic and complex problems. The constant rapid movements of the beads and the combinations of numbers require focus and concentration to depict the numbers and required operations accurately. To be considered an expert on the abacus, one would have to master many areas of cognition (Wang, 2020). As the students continue to maneuver the beads, the transfer from the manual becomes an automatic mental practice.

The concept of transitioning from the use of the concrete abacus to seeing the device and calculating mentally is called a mental abacus. Mental abacus (MA) is a technique of performing fast, accurate arithmetic using a mental image of an abacus; experts exhibit astonishing calculation abilities (Barner, 2016).

Mental Abacus

The use of the abacus dates back to ancient Africa and ancient China. It is a tool that enables one to compute rapidly instead of paper and pencil or the materials available during that era. The abacus has evolved with different countries adjusting the apparatus to suit the needs of their users. The Chinese adapted the tool and added beads to the manipulative, making the first adaptation of the abacus that is widely utilized today. The intention of the use of this instrument was not educationally based. It was developed primarily as a means of writing numbers and to accurately complete computations rapidly. The apparatus is still applicable and is widely utilized in classrooms in industrialized countries today, even though some computers and calculators perform the same tasks. The abacus is widely used in the classrooms of Asian countries. Countries that utilize the abacus have performed better than the United States (Trends in International Mathematics and Science Study-TIMSS, 1996). One possible reason could be the cultural acceptance of the tool in the classroom (Osama, 1993).

"Learning is a necessary and universal aspect of the process of developing culturally organized, specifically" to enhance "human psychological function" (Vygotsky, 1978). Vygotsky, a preeminent educator and psychologist, has made an important observation on the value of education. Vygotsky believed that an individual's ability to engage in higher mental processes is ingrained in social processes. Therefore, he emphasized an individual's social and cultural experiences and based the individual's development on these experiences.

Vygotsky was a firm believer that cognitive abilities develop as a result of the acquisition of specific skills. He also believed that the wherewithal for intellectual development in children is innate (Vygotsky, 1978). His theory of Higher Mental Function says that the collaboration between an individual's memory, perception, sensation, and attention make up one's Elementary Mental Functions. However, this function is further developed due to our interactions with the environment and, more importantly, our social surroundings. Vygotsky coined the term "intellectual adaptation" and said that children could easily maneuver mental functions and make necessary adjustments that coincide with their cultures. He firmly believed that intellectual adaptation to the culture is affected by their cognitive functions. He firmly stated that children can develop higher mental functioning. Understandably, he concluded that one such higher function is the mental abacus (MA; Vygotsky, 1978).

It has already been observed that the mental abacus is an important acquired technique that enables individuals to perform mathematical computations using the image of an abacus mentally. Interestingly, Hatano et al. (1978) utilized the abacus to support the work of Vygotsky. They determined that the abacus skills could be transferred to learned tasks.

The effectiveness of the abacus is undeniable. It works so well because it helps the user to internalize the fundamentals of what they are doing. By using the abacus, students understand the basics of math instruction. By utilizing the abacus to introduce the concept of numbers and the operations of using the numbers, students can understand the abstraction of numbers. The numbers become more concrete and palpable as the students move the beads and complete their calculations from the beginning to the end. The whole process is felt and visually captured in their eyes and minds. They have absolute control of what they are doing. In short, the abacus is an excellent instructional tool or manipulative utilized to help students easily complete basic and advanced operations with numbers. According to Barner (2016), the abacus assists students in representing exact quantities using the position of counters, whose historical origin dates to 1200 AD.

Today, the abacus is utilized mainly in countries like India, China, Japan, and Singapore. The process of maneuvering the physical abacus becomes etched in the brain through consistent practice. As previously explained, the physical motions of moving the beads on the apparatus assist the user in memorizing the process. The physical abacus becomes transformed into a mental image, thus creating the mental abacus. The mental image is then used to perform mathematical computations at a rapid rate. Students proficient in utilizing the abacus can become so well versed in the technique that they perform calculations faster than others and can figure out the same problems more quickly.

Such is the case with one of the instructors in this study, Jeonghee Lee, who is presently the world champion in multiplication, division, addition, and flash mental math (where numbers are flashed on a screen and instantly calculated in one's head). She recently broke the world record in each of these categories. In the addition category, she could add a string of 100 five-digit numbers in less than 1 minute. These phenomenal abilities can be demonstrated by acquiring mental abacus skills (Hatano et al., 1977). Evidence shows that mental abacus users can perform calculations with astonishing speed and accuracy. Stigler et al. (1986) examined Asian children's development of cognitive abilities and observed what effects the abacus had on them after receiving abacus skills training. They substantiated that children acquire or develop their general cognitive abilities when they learn a new skill (Barner 2016; Stigler, 1984; Vygotsky, 1978). These researchers studied the effects of MA on Taiwanese children. The abacus is part of the elementary math curriculum for students in fourth and fifth grade. After being exposed to the abacus in class, the children developed the mental use of the actual physical tool-mental abacus. The students exposed to the abacus training displayed the ability to calculate math problems mentally with phenomenal accuracy and speed.

In a related study, researchers looked at students from Taiwan who possessed diverse abilities on the abacus (Barner 2016; Stigler, 1984; Vygotsky, 1978). The students in Taiwan utilized the Soroban abacus as part of their math curriculum. The students were trained in the physical abacus daily. The consistent use of the physical tool helped the students to internalize the tool mentally. As part of their daily practice, the teacher tested the students and computed math problems mentally. A significant emphasis was placed on their ability to mentally calculate problems as early as 1st grade (Stigler et al., 1986). As a result, the students were able to visualize the image of the abacus and utilize the mental image to solve problems in their minds (Stigler, 1986; Wang, 2020).

From the American point of view, the goings-on at Dongyuan Buxiban, an elementary school abacus program in Taiwan, are quite impressive. Children go there after school and usually sit on long benches in large rooms filled with students. A typical mental abacus calculation exercise begins when the teacher, standing at the front of the room, raises his hand, whereupon the room falls silent in anticipation. The teacher then reads aloud a list of 20 three-digit numbers as fast as he could, so fast that the numbers are almost unintelligible. Finally, after the last number is read, every hand in the room shoots up, and the teacher calls on one child to report the sum. Usually, the child's answer is correct (Stigler et al., 1986).

The math curriculum in Taiwan introduces students to the abacus in the 5th grade. The students are subjected to the basic math computation of the overall math curriculum; however, the abacus is an additional tool utilized school-wide as the students get older. In the study with the Taiwanese students, the purpose of the study was twofold:

1. To look at and document the achievements of children by gathering basic data on speed and accuracy of abacus and mental calculation, as well as information on the relationship between levels of training and practice and resulting expertise; and
2. To describe the nature of mental abacus skill to determine what aspects of the physical abacus and its operation are represented in the cognitive skill.

Students who performed well on the physical abacus apparatus did not all have the capacity to complete all of the problems given to them to perform mentally. The students were categorized based on their abacus level as beginners, intermediates, or experts. The experts had been exposed to the abacus for over 4 years with additional training after school on techniques on how to perform mental abacus. The intermediate level students had been exposed to the mental abacus practices for approximately 2 years, and the beginners only had the physical abacus training received in school. All students performed within the same range in their math classes from 85-95 on a 100-scale score (Steigler, 1984).

While all the students in the study had the basic background knowledge of the physical abacus, the transfer of skill to perform mental abacus calculations was not automatic. The beginners in the study had tremendous difficulty performing mental calculations. The intermediate and expert groups who had additional mental abacus training performed significantly better than the students who had as many years working on the physical abacus as the students who had the additional mental abacus training. One would imagine that the image of the physical abacus would be mentally adapted, and the students would all be able to effectively calculate problems as rapidly as those who had the additional mental abacus training.

While computation is a skill widely utilized in mathematics, it is not a skill that is overly emphasized in the United States (Stigler, 1984). Other countries, however, use computations and mental computations much more than the U.S. However, not much value has been placed on these skills. For example, these skills are used more in some Asian countries. In these countries, acquiring these skills is critical, so specialized centers focus on helping students master these techniques (Stigler, 1984). Stigler's research included students from the United States attending the University of Michigan who were accounting and mathematics majors. The participants felt they could compete mentally based on the content training.

All the American subjects reported using the same method of mental addition: Working from right to left, they added the numbers of each column one at a time, remembering each successive digit of the answer while working on the next column. This method follows the way most people would add with paper and pencil. None of the American subjects had experience with abacus calculation. The results were that the Chinese students beat the adults in every trial, and the children all outperformed the adults. Understandably, all the students were trained in the mental abacus techniques (Stigler, 1984)

As the research demonstrates, Asian students consistently outperform the students in the United States (U. S. Department of Education [USDOE], 2010). There are several reasons cited for the differences in scores, one being the use of the abacus in the elementary school grades (D'Ailly, 1992). The students are introduced to the abacus at an early age. As a result, they acquire a comfort level with numbers through the use of the apparatus. As their educational experience continues, their ability to interact with this manipulative increases; thus, they learn to compute at an ever more rapid rate with the tool. Completing calculations at high speeds enables them to complete standardized tests with greater speed and accuracy.

It is undeniable that abacus skills enhance mental calculation, which, in turn, transfers to component mathematical sub-skills of numeration and calculation. These sub-skills equally affect mathematics achievement. Moreover, the transfer from abacus skills to numeration directly impacts mathematics achievement through numeration's effect on mathematical applications. These findings are consistent with the explanation of skills transfer in terms of improvements in component sub-skills. In the case of the abacus, improvement in sub-skills seems to result from learning the effective mental analog of the mental abacus (Stigler et al., 1986). There is also evidence that working memory is affected through the acquisition of mental abacus skills.

Working Memory

Working memory is vital to our learning. It is the area of the mind concerned with high-speed memory used for storing data for immediate use in other studies. Working memory is integrated and deeply woven into the skill and concept of the abacus. The process of the abacus involves tracking beads and maneuvering them to represent the numbers. Focusing on the beads encourages the students to become more focused and may increase mental abacus skills. Research done by Roberts et al. (2015) demonstrates that an individual's exposure to formal learning helps to build working memory. It has been said that practice makes perfect. If an individual practices a particular skill, the belief would be that that individual will get better at that skill. Neuropsychological and brain studies indicate that brain activity is altered if individuals have consistent training (Buschkuehl et al., 2008). In the area of working memory, studies have supported the notion that MA enhances children's problem-solving skills in mathematics as well as reading (Klingberg, 2010).

A recent study by Buschkuehl et al. (2008) on the neural pathway underlying a numerical working memory task in abacus-trained children and associated functional connectivity in the resting brain examined how abacus training affects structural connectivity. The findings indicated that if individuals receive extensive mental abacus training, it enhances the part of the brain that controls the motor and visuospatial processes (Hu et al., 2011). The study suggested that the individual's capability to calculate was improved when exposed to abacus training. Studies on working memory have indicated that students may acquire gains in their thinking abilities through the use of MA. It is generally believed that our cognitive abilities can be improved with some training, but it is anticipated that working memory and even attention span may increase due to the abacus training.

After examining the neural mechanisms that underlie the memory of visual numerical information in abacus trained children, it was found that there was an impact on the way the brain functioned (Hu et al., 2011). The increased functioning of the brain enabled the students to perform at a more rapid rate in terms of mental calculations than their counterparts. The students in the study were trained on the abacus for approximately 3 years. Through the training, they acquired the image of the abacus mentally and thus were able to perform the calculations in their minds at rapid rates. They were able to perform calculations of strings of numbers faster than some utilizing calculators. The findings indicate that children trained on the abacus showed growth in their ability to focus and recall information (Yao, 2015).

In another study, researchers looked at the temporal course of numerical processing in mental abacus calculations using an Electroencephalographic (EEG) and event-related potential (ERP) techniques. The researchers had the participants examine the efficiency of "extracting numerical information both intentionally and automatically" (Wang et al., 2013). Subjects took a look at a couple of numbers and examined them for magnitude and physical size. They wanted to see if the time it took the participants to respond to the numbers would vary. If there was a relationship between the numbers (congruent, etc.), the participants trained in the abacus responded faster than if there was no relationship. The hypothesis was that those students exposed to the mental abacus training would complete numerical functions more effectively and efficiently than those not subjected to the training. Their response time to problems that were posed was timelier than the control group.

The abacus training group showed higher efficiency in numerical processing than the control group because the numerical information becomes more salient for the abacus group. Mental abacus training could strengthen the relationship between symbolic representation and numerical magnitude so that the numerical information processing became more automatic in abacus children, as reflected in their higher numerical processing efficiency (Yao, 2015). Studies like the one above argue that mental abacus training supports working memory. The nonlinguistic representation appeals to the visuospatial working memory and aids in the learned method utilized in abacus training. The ability to maneuver items and manipulatives has more of an impact on an individual's working memory. Verbal directives and other spoken tasks create more interference for working memory (Frank & Barner, 2012; Hatano et al., 1977). Mental Abacus training appears to stimulate the brain region that impacts working memory (Chen et al., 2006; Du et al., 2013).

The Soroban abacus allows an individual to chunk four to five sets of beads together. This number of beads manipulated at once coincides with the brain's capacity limit outlined in working memory studies (e.g., Alvarez & Cavanagh, 2004; Atkinson et al., 1976; Luck & Vogel, 1997; Todd & Marois, 2004). Mental abacus users chunk three to four columns and do so, treating each column as an individual object in working memory (Frank & Barner, 2012; Stigler, 1984). This information suggests that the training mental abacus users received helped them take a concrete set of columns and transform it into abstract symbolic objects and sets (Ball, 1992; Hatano et al., 1987; Wang, 2020). The study on Mental Abacus that have been conducted thus far all seem to focus on highly motivated students, possessed a great degree of knowledge and performed well on mathematical concepts and were apt to learn math in a visuospatial format (Frank & Barner, 2012; Hatano et al., 1977; Huang et al., 2015). This study varied because it concentrated on a general population of learners with no set predispositions to learn math. Since these students represented a general pool of students, it would be interesting to see if the randomized controlled group performs as well as the experimental group.

It is significant to note that working memory theory plays a significant role in the psychology field. This influence derives, at least in part, from links between measures of working memory capacity and a wide variety of real-world skills. Extensive research has been conducted in children and adults to test the capacity of their working memory. Working memory has been defined as a "brain system that provides temporary storage and manipulation of the information necessary for . . . complex cognitive tasks" (Baddeley, 1992; Wang, 2020). The purpose of working memory, as opposed to short-term memory, is to actively keep information readily available while engaging in other everyday activities (Case et al., 1982). To assess the skills of working memory, researchers have utilized both verbal and non-verbal assessments. Such assessments are critical because it is believed that the higher an individual's working memory, the more capacity the individual has to perform intellectually (Engle, 2002).

This notion of working memory capacity is synonymous with executive attention and, in turn, leads to the view that individuals with high working memory capacity will perform better on tasks requiring the inhibition of distracting information. Several lines of evidence support this idea. For example, individuals with high working memory capacity perform better on an anti-saccade task. They have to inhibit an eye movement towards a visual cue that occurs on the opposite side of the screen to a brief stimulus that requires a judgment (Kane et al., 2001).

As it pertains to the present research, working memory contributes to the students' ability to focus on the abacus apparatus and adopt its mental aspect to help them apply the concepts being taught. The training the students receive should be able to transfer to other tasks they can perform. The training the students received with the abacus should increase domain-general attentional capacity and enable them to complete different tasks. Working memory training would be expected to show both near and far transfer effects (Barnett & Ceci, 2002). Near-transfer effects are effects on tasks performed following training on verbal working memory tasks. In contrast, far-transfer effects are effects on tasks quite different from those trained, such as improvements on IQ tests following training on working memory tasks (Melby et al., 2012).

As the research unfolds, younger children showed significant gains with working memory training. Some inferences can be drawn from the meta-analysis of the data in the study. It shows that there are gains in the verbal and nonverbal tasks assigned during the study. "Importantly, the pattern of results for transfer effects is highly consistent across studies" (Melby et al., 2012, p.281), and working memory has increased. This finding supports the hypothesis that the mental abacus skill directly affects an individual's math ability. If students can become more comfortable with math and mathematical concepts, there could be significant mastery of the basic concepts that often seem to be confusing under the theory of near-transfer effects.

Gender and Math

"Girls don't do math" is a widespread cultural stereotype in the United States. In addition, studies with both adults and children (Lummis & Stevenson, 1990) have shown that people in the United States believe that Math is stereotypically a male domain. "Given such stereotypes, a tendency to keep the related concept of self, gender, and math consistent with one another, called cognitive balance may play a role in why a young girl would say—and possibly believe—that math is not for her" (Cvencek et al., 2011, p.770).

What would cause a student to conclude that because of her gender, she is not good at math? What is it at such an early age that girls tend to shy away from math and boys tend to embrace the content? While it involves numerous interconnected concepts, gender identity as it relates to math is the main focus. Research indicates that even with adults, there is a strong association that if a woman identifies herself as female and with a weak image of themselves, that association translates into a weak association with math (Nosek et al., 2002). It has been found that girls as early as 1st grade tend to rate themselves lower in math performances than do boys. However, this phenomenon is not true for other subjects like reading, spelling, or social studies (Fredricks & Eccles, 2002). This disbelief eventually impacts female students' interest in careers associated with mathematics (Denissen et al., 2007; Liben et al., 2001).

While the thought or concept of math gender stereotypes may be tied to self-esteem, to test that hypothesis, researchers (Greenwald et al., 1998) adopted an implicit association test that can be administered to adults. This computerized assessment that inventories associations related to concepts were tweaked and utilized to assess children's outlook regarding math and reading. The two content areas were selected due to the mandate for students to take both subjects throughout their educations. Another factor that played a role in selecting the two subject areas was that standardized assessments usually encompass both areas. The test measured strings that related one subject matter to another—in this case, math and reading. The researchers were also interested in determining if there would be any significance in how girls and boys related to different subjects. One of the most important concepts of the study was to determine if "American elementary school children will associate math more strongly with boys than with girls and both implicit and self-report measures" (Cvencek et al., 2011).

The idea that girls are not as good in math as boys is derived from some level of stereotype. According to Battey (2018), stereotypes can be separated into two underlying processes: the first is automatic, unconscious, and implicit; the second is controlled, conscious, and explicit. Devine's study of implicit and explicit bias was conducted on adults, and while a positive correlation was found between the two, the correlation was quite weak (Bigler 2002; Rudman, 2004). Both suggest that implicit and explicit biases contribute to the shaping of children's self-image. Greenwall et al. (2002) also researched how attitudes, stereotypes, and self-concepts contribute to how individuals organize themselves. This balance theory, first coined by Heider (1949), was studied intently and expanded by Greenwald et al. (2002). It confirmed that individuals tend to organize or view themselves based on societal and family constructs. Their study analyzed children's math gender stereotypes and math self-concepts. The study also focused on how implicit and explicit biases may affect or impact gender stereotypes regarding math education (Greenwald et al., 2002).

The study indicated a correlation between math gender stereotypes and math self-concept using both implicit and explicit measures. It was found that boys responded better to mathematical concepts and math education than girls did. The study was initially conducted with adults. The outcome was that men tend to identify more with mathematics than women. The results of the same study in children mirror those in adults. These results imply that math gender stereotypes are perpetrated as early as elementary school (Greenwald et al., 2002).

Aaronson and Good (2003) found that students' math scores were directly impacted by activities that preceded the assessment. While the children were not privy to the gender-specific stereotypes pertaining to mathematics, their study supported the thought that boys tend to do better in math. One particular example in the study relates to the evaluator sharing a gender-neutral story. Upon completion of the story and asking the students to recite what the story was about because of the subject matter math, most of the students referred to the characters using masculine terms to describe the main character in the story revolving around math, even though the gender of the character was not shared during storytime. This stereotype that associates math with boys is a United States stereotype. The study also found that the stereotype affects boys differently than it affects girls. Studies indicate that gender differences tend to develop during the formative years of finalized education (Ambady et al., 2001). Adopting the negative stereotype of girls not liking math leads to poor standardized test scores for older female students. However, it was found that boys and girls perform equally well on achievement tests in lower grades. While young girls show a weaker sense of identification with math than their male counterparts, they continue to perform better if not as well as their male counterparts, according to Cvencek et al. (2002).

Cvencek et al. (2002) also studied partnership consistency in math gender stereotypes. To further examine the concept of gender and math, Cveneck et al. (2014) took a look at cognitive consistency among young math students in Singapore. According to the authors, "cognitive consistency refers to an intra-individual psychological pressure to self-organize one's belief and identity in a balanced fashion." This study is significant for two reasons. One is because Singapore is classified as a "collectivist" culture where the emphasis is more on the group than the individual like that of western cultures (Brewer & Chen, 2007). Second, Singapore is one of the countries that tend to outperform other countries in mathematics.

On standardized math assessment, Singaporean children outperform North American children based on standardized international evaluation of school achievement, the Trends in International Mathematics and Science Study (TIMSS) and the International Student Assessment (PISA). As a result, Singaporean children rank near the top of the international ranking. For example, Singaporeans have participated in every cycle of TIMSS testing (1995 to 2007). Its elementary and middle school students—both boys and girls—were among the top three in the world in mathematics in each assessment (TIMMS, 2007).

Moreover, Singapore girls scored higher than Singapore boys. However, the math-gender stereotype of Singaporean elementary school children has not been assessed. Thus, we do not know whether Singaporean girls, who are among the world's leaders in math achievement, hold the pervasive North American stereotype that “math is for boys.”

While we do not know if the stereotype is held in Singapore. However, it is held among school-age Elementary North American children. This stereotypical belief is prevalent in both males and females. They believe that boys are better at math than girls (Ambady et al., 2001; Gundetson et al., 2012). The traditional mode of inquiry around stereotypical beliefs about mathematics has been explicit-meaning. It involved asking students how they feel about math and who does better (Herbert & Stipek 2005). However, the push recently has been to evaluate the unconscious, implicit, and automatic aspects of learned stereotypes (Jacoby, 1991). The validity of the math gender stereotypes was assessed using both implicit and explicit assessments with Singaporean elementary school students.

According to Steele’s (2003) stereotype stratification model, the possibility of an existing stereotype between male and female math ability may not exist because of the cultural differences between American and Singaporean students. The fact that Singapore leads the nation also in test scores shines light on testing the theory of gender differences in math. According to Abhijit (2006), “Singaporean children might not adopt the stereotype that math is for boys. On the other hand, Singaporean children live in an English-speaking culture that is permeated with American media, and they may catch the stereotype that math is for boys.”

The study results on the implicit measure boys associated math with their gender significantly more than girls did. Similarly, boys are more likely to pick the same gender character as liking to do math more on the explicit measure. It was surprising to see the study results when one considers that Singaporean boys and girls do not perform much differently in terms of mathematics, with the highest achievers in mathematics usually being girls.

The formative years of schooling are pertinent when it comes to developing an individual's concept of self. Whether intentional or not, children notice implicit and explicit expressions from those around them that are significant contributors to their lives. Children inevitably will compare their performance with the performance of other students (Marsh, 1989). The notion of gender stereotypes influenced a child's self-concept and possibly impacted that child’s academic achievement (Cvencek et al., 2011). The development of mathematical performance can be linked to several different factors; these factors include, but are not limited to working memory, number competencies, and phonological awareness (Butterwirth, 2010; Krajewski & Schneider, 2009). While these factors are important, individuals' motivations and affect are also key (Lee, 2009).

Regarding motivation research, the individual’s sense of self is a pertinent construct in how they view themselves academically (Marsh & Craven, 2006). “It can be defined as a mental representation of one’s ability in a specific academic context and is formed by experiences in achievement-related situations and the interaction between the environment and significant others. (Shavelson et al., 1976). A positive gender-related outlook is associated with positive self-esteem, how engaged an individual is cognitively, and how motivated they are to learn (Helmke, 1999). Research indicates that when students are engaged in activities that do not match their self-concept, their interest in future academic activities declines (Denizen et al., 2007; Liben et al., 2001).

Research on gender differences usually focuses on middle school and high school children (Moller et al., 2006). In contrast, research revolving around primary or elementary school-age children is scarce (Koller & Marsh, 2009). The thought of self-concept is important to gender differences because the self-concept of boys and girls vary. The oral performances of younger females regarding speaking are significantly higher than the male self-concept (Marsh et al., 1991). However, the young male self-concept is higher (Whom et al., 2011). The divide tends to increase as boys and girls get older (Jacobs et al., 2002). The research around gender and age differences in elementary students varies. Some research supports the notion that academic gender differences emerge at the end of elementary school (Eccles et al., 1993; Ehm et al., 2011). Other research around academic self-concept shows that girls' self-concept of their performance in math is not as strong as that of their male counterparts (Jacobs et al., 2002).

Cognitive Development

When it comes to performance in mathematics, a child's self-concept usually starts more general and eventually becomes more differentiated as they experience different activities (Harter, 1983). Research has indicated that children's perceptions in kindergarten and 1st grade are usually pretty general, with more differentiation coming when children hit 3rd grade (USDOE, 2010).

The Department of Education appears to agree with this research when examining the outlined standards for 1st and 2nd graders. The major focus is on four critical areas of the mathematical standards for 1st grade: (a) developing understanding of addition subtraction and strategies for addition and subtraction within the twenties; (b) developing an understanding of whole numbers relationship and place values, including grouping in tens and ones; (c) developing an understanding of linear measurement and measuring lengths as iterating units; (d) reasoning about attributes of, and composing and decomposing geometric shapes. The standards for 2nd grade are basically the same, just building on the foundation that has been established in the 1st grade. Therefore, the standards for 2nd grade in mathematics instructional time should focus on these four critical areas: (a) extending understanding of basic 10 notation; (b) building fluency with addition and subtraction; (c) using standard units of measurement; (d) describing and analyzing shapes (NJDOE, 2016).

The building block grades and standards are comparable between the 1st and 2nd grades. The major shift in the standards is noticed in the 3rd grade.

Participants on the team to develop national standards for mathematics challenged each other on establishing standards for young children. Most of the discussion around developmental differences is that children may not be able to handle the criteria outlined in the national student learning standards. The term developmentally appropriate was tossed around in the discussion to address developmental differences in the learning standards. As the discussion got deeper, participants began to question whether 1st and 2nd graders were ready to handle place values. How well 1st and 2nd graders would handle these concepts of grouping or understanding how numbers expand was questioned (Clements & SARAMA, 2014; Susan et al., 2012). While the standards for 1st graders involved working with numbers up to 100 and basic addition facts, the standards for 2nd graders expanded the concepts. While this is one example, it is an example of the extensive discussion that established specific standards for specific grades. The argument holds that there are major differences between the mathematical performances in general 1st and 2nd graders. While their research around fundamental differences between 1st- and 2nd-grade students regarding mathematics is limited, the existing research consists of mixed results and opinions around students' performance (Keller, 2014) seems to believe that students can go beyond the expectations of adults. The other side of the argument is to be mindful of what expectations young scholars have to achieve in the mathematics department.

Conclusion

Barner et al. embarked on an abacus study during the 2015-2016 school year. While they and other researchers have conducted studies abroad on the effects of the abacus and mental abacus on students, the focus was often on older students and adults. As noted, studies have examined elementary school students. However, fewer studies have been conducted on an international level. An even more limited number of studies have been conducted in the U.S. (two were found with American children in the past 5 years).

The literature review indicated that extensive use of the abacus in the studies' participants yields positive results. Students exposed to the physical abacus internalized the teachings and could translate the physical apparatus into a mental tool for rapid computation. The research also supported the notion that children made positive. Memory gain after being exposed to the physical/mental abacus process.

While the study of the abacus has been limited to 1st- and 2nd-grade students, this study will help to provide more information on the use of the apparatus in small children. While the children were exposed to the tool for only 1 year, they had the opportunity to learn the basic skills needed to operate the tool and apply the operations to the mathematical concepts taught through the district curriculum for the entire year.

Through exploration of secondary data, this researcher looked to explore the significance of the mental abacus usage and how or if it impacted students' performance on working memory and the students standardized assessment scores.

CHAPTER 3

METHODOLOGY

Introduction

The purpose of the study is to determine the effects of Physical Abacus and Mental Abacus training on the math scores and working memory of 1st- and 2nd-grade students. The working memory is an important aspect of the operations because the students have to be able to recall how to group the beads to represent specific numerical values. The following questions were examined to assess whether there are any significant impacts on the students' scores:

1. Does implementing the abacus curriculum improve the overall mathematics achievement of 1st and 2nd grades as measured by the STAR assessment diagnostic achievement test?

   Null Hypotheses:

   a) There is no statistically significant difference between the overall pre- and post-mean scores for 1st graders who were exposed to the abacus versus those who were not.

   b) There is no statistically significant difference between the overall pre- and post-mean scores for 2nd graders exposed to the abacus versus those who were not.

2. How do physical abacus and mental abacus use affect the assessment scores of 1st graders versus 2nd graders?

   Null Hypotheses

   a) There is no statistically significant difference between the pre- and post-growth scores for 1st graders versus 2nd graders.

3. Is there a statistically significant difference in the growth in mathematics test scores of students who underwent the abacus training compared to students in the control group, and does grade level affect the outcomes?

   Null Hypotheses:

   a) There is not an interaction between grade level and participation in abacus training.

If the null hypothesis is not rejected:

   a) There is no difference in the growth for the different grade level STARS scores and

   b) There is no difference for students in abacus and control groups.

4. Does the mental abacus improve students' working memory?

   Null Hypotheses:

   a) There is not an interaction between grade level and participation in abacus training on working memory.

If the null hypothesis is not rejected:

   b) There is no difference in the growth for the different grade level scores and

   c) There is no difference for students in abacus and control groups.

5. Is there a statistically significant difference between male and female students exposed to the physical/mental abacus training?

   Null Hypotheses:

   a) There is no significant difference between male and female students in math growth scores when exposed to the physical/mental abacus training.

To assess the effects of the mental abacus on 1st and 2nd graders' math performance, previously collected archival data were utilized to determine any significant improvements in the students' math performance. In addition, to evaluate if the mental abacus impacts the students' working memory, a secondary analysis was conducted on the quantitative data from a previous study by Frank and Barner (2016) assessing mental abacus use among elementary school students.

Research Design

In this quantitative study, the researcher utilized secondary data collected in 2016 to measure the outcome of a baseline model that includes a growth mindset to determine the effects of the intervention of Abacus/MA on the students' standardized assessment scores development. Secondary data is the use of existing data that is readily available to be evaluated. This methodology enables the opportunity to analyze data already collected (Donnella et al., 2011). Analyses were conducted to determine whether there were any significant relationships between administering the abacus curriculum and students' performance. In addition, the study looked for interactions between groups (1st grade and 2nd grade and girls versus boys) assigned the abacus training versus those who did not receive the training to determine any significant improvements over time.

Overview of the Original Study

In the initial study (Barner et al., 2016), students were assessed at the onset of the school year utilizing the Renaissance Learning Math Star Assessment before implementing the abacus instruction. The Renaissance Learning Star Math post-assessment was administered at the end of the school year to determine if any significant gains were achieved. In addition, a pre-and post-assessment developed and administered by Barner and Frank was utilized to determine the effects of mental abacus instruction on 1st- and 2nd-grade students' math scores. There were two different sets of data evaluated. The first set of data consisted of the students involved in the working memory experiment. The number of students tested for this portion of the study was significantly smaller than the abacus study population. A partnership with Frank and Barner, professors from UCLA and Stanford University yielded the results of the working memory assessment. They needed to obtain permission from parents to have students in the memory study. The visiting professors did not receive a response for every parent's participation in the working memory study. Permission slips were obtained for 164 students in the working memory study, and a population of 338 students was utilized for the MA study. The results were assessed to evaluate whether there were any significant differences between the performances of girls and boys on the assessments. The study also evaluated whether there were any developmental differences in the performance of 1st- and 2nd-grade students as it pertains to memory and math performance. "Improvements to spatial working memory in general from focused practices on a particular task-is generally thought to be rare. The cited students found significant differences in performance on classic tests of spatial working memory after MA training" (Barner & Frank, 2012). If that is indeed true, then the results of this study should support the claim.

Original study methodology[1]

The original study used a quasi-experimental design with a control and experimental group. The participants of the study were randomly selected to participate. The 1st and 2nd graders attended a large suburban elementary school in the Northern part of the United States. In this study, 13 classes were the control group. This group received additional hours of the assigned district curriculum, "Math in Focus," a standards-based program. The experimental

[1] For a full description of the methodology of the original study, see the Barner and Frank (2016) article cited in the bibliography.

group of students received abacus and mental abacus (MA) training half the time in their math class; the other half was spent adhering to the district Math in Focus curriculum. The students in both the control and experimental groups were also administered a general cognitive measure for working memory.

An elementary school in a Northeastern state in the United States, located in a suburban area, was utilized for the study. The multi-cultural school had a blend of diverse ethnicities and various socioeconomic statuses (see Table 1):

Table 1

Count of Lunch Status Column Labels

Grade	Free Lunch	Do Not Receive Free Lunch	Reduced Lunch	Grand Total
Grade 1	61.73%	30.10%	8.16%	100.00%
Grade 2	68.55%	22.64%	8.81%	100.00%
Grand Total	64.79%	26.76%	8.45%	100.00%

Of the table above, a breakdown of the ethnicity of the students can be found below:

Table 2

Count of Ethnicity

Grade	Asian	Black	Hispanic	Multi	Native Hawaii/ Pacific Islander	White	Grand Total
Grade 1	1.53%	25.00%	48.47%	2.04%	0.00%	20.92%	100.0%
Grade 2	1.89%	29.56%	59.75%	0.00%	0.63%	8.18%	100.0%
Grand Total	1.69%	27.04%	53.52%	1.13%	0.28%	15.21%	100.0%

The school has 11 1st grade classes and 13 2nd grade classes for a total of 24 classrooms. The classrooms were randomly assigned to be part of the control and the experimental groups. As part of the study, four classes of students were classified for special services. The school has a Dual Language Program. This program is for native and non-native speakers of English. In the 1st-grade Dual Program, students from Spanish-speaking countries, with Spanish as their native language, are placed in the program upon enrollment into the district. Four of the classrooms in the study were Dual classrooms. In addition, there were 12 general education classrooms. Five of the general education classrooms were inclusive. The students in this class consisted of students who were high functioning, average and classified students.

Curriculum/Intervention

The students and teachers in the study were trained in the Abacus curriculum. Each participant, student, and teacher was given an abacus. They were taught how to hold the apparatus and how to utilize the tool to represent values. The working memory is an important aspect of the operations because the students have to be able to recall how to group the beads to represent specific numerical values. The students are taught a concept on the abacus, and then they practice that concept for the week. The program continued to build and expand on place value as the concepts were created. An outside agency provided the training for the teachers in the abacus/MA curriculum. The company provided all the curriculum materials for the students and the teachers. Master Jeonghee Lee supported the teachers and the students with the mental abacus training.

The math period was 90 minutes long. During that time, the control group was engaged in the regularly scheduled program, "Math in Focus," for the class duration. According to Houghton Mifflin Harcourt, the company that published the program, the math program "Scaffolds instruction to meet the needs of individual learners with hands-on learning and visual models that support and optimize learning. Math in Focus is a program that focuses on a gradual transition between concrete and abstract representations" (HMH, 2013). The students attend math classes daily. During the study, the students in the control group received their regular instruction.

In contrast, those in the experimental group received 45 minutes of Math in focus instruction and 45 minutes of MA training 3 days a week. The other 2 days of the week, the students received the full 90 minutes of Math in Focus instruction. While manipulatives are prevalent in the Singapore math program, the curriculum focuses on number sense. In addition, the abacus curriculum gets students comfortable with the apparatus and teaches high-level skills like place value, additional rules, etc. The teachers who were selected for their class to be exposed to the abacus instruction were trained on the teaching techniques of the abacus by the outside agency.

Setting

The setting of the study is an elementary school with grades 1, 2, and 3. The school is labeled a small suburban school district; however, the population resembles an urban setting, with approximately 70% of the students receiving free/reduced lunch. All students received their individual abacus workbook and abacus for the study. The abacus was distributed and collected each day, so taking it home to practice was not an option. Several parents purchased the abacus apparatus at home so their children could practice at home.

Participants

For the study, I worked with two different sets of data. The breakdown of the participants for the working memory is shown in Table 3. These numbers are significantly lower than the data for the other research questions, partly because the researchers had to obtain permission from the parents to assess their students for their study.

Table 3

Working Memory Participants

	Grade	Children enrolled	Consent form received	Data collected
Control	1st	79	49 (62%)	26
	2nd	99	51 (52%)	44
Mental Abacus	1st	85	46 (54%)	35
	2nd	75	70 (93%)	59

For the working memory aspect of the study, consent forms were sent home with all students in Grades 1 and 2 and followed up with several school-wide announcements. All children from participating classrooms were enrolled in the study if they had valid consent forms, though a small number were sick or otherwise absent and were not tested in particular tasks or time points. Participants were only included in analyses if they had been tested at both time points for the working memory aspect of the research. We also received consent forms from children in excluded classes. Table 4 gives an overview of the number of participants in different groups in the study (Barner et al., 2016).

Table 4

Participants

	Control		Working Memory	
	Grade 1	Grade 2	Grade 1	Grade 2
N participants	26	44	35	59
Mean age	6.52	7.56	6.37	7.46
Median Age	6.49	7.51	6.32	7.41
Std. Dev. Age	.39	.41	.29	.36
N Hispanic	15	20	14	26
N African-American	7	13	11	24
N Mixed Race/Other	4	11	10	9

For research questions 1, 2, and 4, the population was larger. The random students who received the abacus training schoolwide were also assessed pre and post with the STAR Assessment. The students who participated in the regular and adjusted abacus curriculum did not have to obtain permission from parents to participate because it was the adopted district curriculum for the school year. Participant data for the abacus study are shown in Table 5.

Table 5

Abacus Participants

	Control		Mental Abacus	
	Grade 1	Grade 2	Grade 1	Grade 2
N participants	79	99	85	75
Mean age	6.905	7.90	6.805	7.84
Median Age	6.81	7.51	6.76	7.41
Std. Dev. Age	0.376	.39	.4175	.3475
N Hispanic	43	39	39	34
N African-American	30	40	31	30
N Mixed Race/Other	6	20	15	11

Measures and Procedures

Two measures were utilized for this study: the working memory assessment and a mathematics assessment.

Working memory assessment. The students were called to the media center for the working memory test at the school year's onset and end. The memory test was conducted over 4 days at the beginning of school and 5 days at the end of the school year. The assessment was administered on a school laptop. The students were assigned different tasks and asked to complete them. The process lasted between 40 to 60 minutes. The tasks the students were assigned can be viewed at https://www.testmybrain.org/launch/mfrank.html (Barner et al., 2016). For the study, the working memory assessment used can be found in the NIH (National Institute of Health) toolkit. In this section of the battery addressing working memory, “The ability to store information until the amount of information to be stored exceeds one’s capacity to hold that information (NIH, 2015).” The students were shown several objects and were instructed to pay attention to them. They were then asked to repeat the objects in size from smallest to largest (i.e., for “cat, mouse, horse, elephant,” the student’s response should be “mouse, cat, horse, elephant”). The students scored a 1, 2, 3, or 4, depending on the number of correct responses in size order. This assessment was administered as a pre- and post-test to the students who participated.

Mathematics assessment. The STAR assessment was administered at the onset and end of the school year to assess the students' fluency in mathematical concepts. The classroom teachers administered the Star Math assessment. All students were given an individual laptop, and they were logged on at the onset and end of the school year. The Star assessment is a progression type of assessment that adjusts itself to each student’s performance level.

The test was completed on the computer. Students taking the assessment were given up to three minutes to answer each question. When the time was almost up, there was a signal that the students received. The students were assessed on basic addition, subtraction, and possibly multiplication and division problems based on the student’s performance. If the students answered the problem correctly, the assessment would adjust to the students' answers, with the questions becoming more complex. The students were then taught the district’s Math in Focus or Singapore Math curriculum in the control group for 90 minutes each school day. The experimental group was taught the district Math in Focus or Singapore Math curriculum daily. They were taught two days for 90 minutes, and the other 3 days, the instruction was split between 45 minutes of the district’s Math in Focus curriculum and 45 minutes of the Abacus curriculum. Three days out of the week, the same format was followed to the end of the school year. During the abacus instruction, the students were given a physical abacus, pictured in Figure 1. They were instructed on the proper ways to hold the abacus and taught to place values on the abacus. Each day they would practice how to represent numbers using the abacus. After getting familiar with the apparatus, the students were asked to complete basic addition computations on the abacus. After the skill was taught on the physical abacus, the instrument was removed, and the students were asked to picture the abacus mentally. They were asked to repeat the additional skills by visualizing the physical abacus mentally. This practice was a consistent part of the procedure. At the onset of the following class, the students would practice the previously learned mental abacus practice before learning a new concept with the physical abacus in class.

Students had to learn the position physically of each bead on the abacus to perform the task of addition or subtraction correctly. Here, the working memory becomes an important part of the research. There was a specific testing window established by the school district to which the teachers had to adhere. At the end of the school year, the STAR Assessment post-test was administered to all students.

Secondary Analysis

A secondary analysis was conducted utilizing data from Barner and Frank's (2016) study. The focus of this secondary analysis was on working memory and students' performance on the Renaissance Star Math Assessment. To address the fourth research question—"Does implementing the abacus/mental abacus curriculum improve the overall working memory of students, pre- and post-test data?"—a spatial working memory change detection task, in which students had to track longer sequences of locations in a spatial grid gradually, was utilized (Barner et al., 2016). The pre/post task assessment, administered by Barner and Frank, was utilized to assess the mental abacus skills acquired. To assess the impact of the mental abacus on working memory and test scores, variations of t-tests and ANOVA were run on the data.

The Renaissance Star Math Assessment pre/post scores for all students were examined to address research questions 1, 2, 3, and 5:

1. Does implementing the abacus curriculum improve the overall mathematics achievement of 1st and 2nd grades, as measured by the STAR diagnostic achievement test?
2. How do physical abacus and mental abacus use affect the assessment scores of 1st graders versus 2nd graders?
3. Is there a significant difference in the growth in mathematics test scores of students who underwent the abacus training compared to students in the control group, and does grade level affect the outcomes?

4.. Is there a statistically significant difference in growth scores of male students versus female students who were exposed to the physical/mental abacus training?

Independent sample t-tests and analyses of variance (two-way ANOVA and ANOVA) were conducted to assess the mental abacus's impact on the students' pre/post paired t-test.

CHAPTER 4

RESULTS

Introduction

The purpose of this study was to determine the effects of Physical Abacus training on the Mental Abacus on 1st- and 2nd-grade students' math scores in a small suburban district in Northern New Jersey. The research questions that were the focus of this study were the following:

1. Does implementing the abacus curriculum improve the overall mathematics achievement of 1st and 2nd graders as measured by the STAR assessment diagnostic achievement test?

Null Hypotheses:

a) There is no significant difference between the overall pre- and post-mean scores for 1st graders who were exposed to the abacus versus those who were not.

b) There is no significant difference between the overall pre- and post-mean scores for 2nd graders exposed to the abacus versus those who were not.

2. How do physical abacus and mental abacus use affect the assessment scores of 1st graders versus the 2nd graders?

Null Hypotheses:

a) There is no significant difference between the pre- and post-growth scores for 1st graders versus 2nd graders.

3. Is there a significant difference in the growth in mathematics test scores of students who underwent the abacus training compared to students in the control group, and does grade level affect the outcomes?

Null Hypotheses:

a) There is not an interaction between grade level and participation in abacus training.

If the null hypothesis is not rejected:

b) There is no difference in the growth for the different grade level STARS scores and

c) There is no difference for students in abacus and control groups.

4. Does the mental abacus improve students' working memory, and does grade level affect the outcome?

Null Hypotheses:

a) There is not an interaction between grade level and participation in abacus training on working memory.

If the null hypothesis is not rejected:

b) There is no difference in the growth for the different grade level scores and

c) There is no difference for students in abacus and control groups.

5. Is there a significant difference in male students' versus female students' math growth when exposed to the physical/mental abacus training.

Null Hypotheses:

a) There is no significant difference in male students' versus female students' math growth scores exposed to the physical/mental abacus training.

Chapter 4 discusses the sample demographics, descriptive statistics, data screening, research questions/hypothesis testing, and a summary of the results. Data were analyzed with SPSS 23 for Windows. The following provides a discussion of the sample demographics.

Sample Demographics

The sample consisted of 338 students, 58.9%, (n = 199) were males and 41.1% (n = 139) were females (see Figure 4).

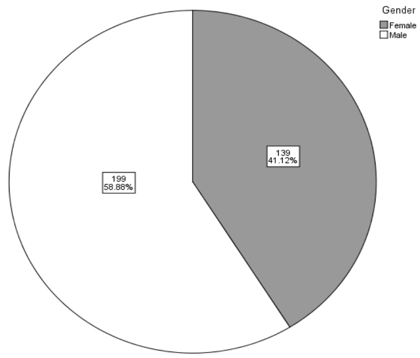

Figure 4. Gender.

Regarding race/ethnicity, 38.8% (n = 131) were Black, 45.9% (n = 155) were Hispanic, 11.5% (n = 39) were white, and 3.8% (n = 13) were Asian or Pacific Islanders. See Figure 5.

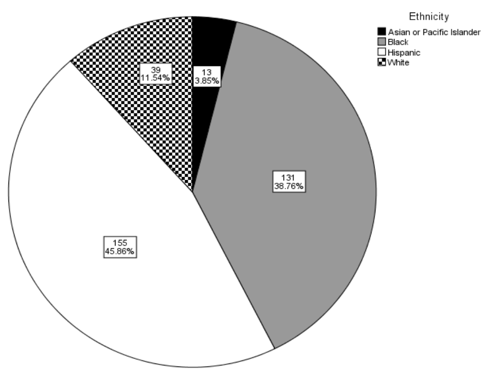

Figure 5. Race/Ethnicity.

Students who received abacus training (51.8%, n = 175) and students who did not receive abacus training (48.2%, n = 163) were approximately equally distributed. See Figure 6.

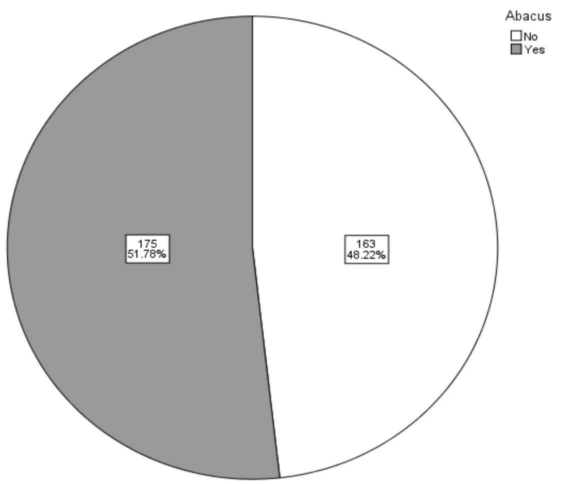

Figure 6. Abacus training status.

Fifty-three percent (n = 179) of students were in the 2nd grade and 47.0% (n = 159) were in the 1st grade. See Figure 7.

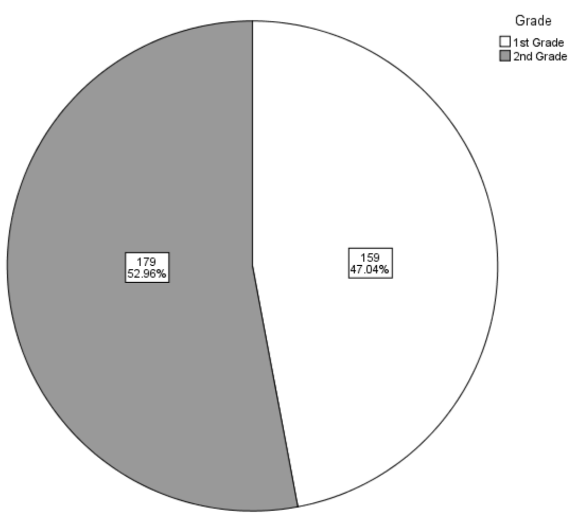

Figure 7. Grade level.

Demographics are summarized in Table 1.

Table 6

Sample Demographics

Variable	Description	n	%
Gender	Female	139	41.1
	Male	199	58.9
Ethnicity	Asian or Pacific Islander	13	3.8
	Black	131	38.8
	Hispanic	155	45.9
	White	39	11.5
Abacus	No	163	48.2
	Yes	175	51.8
Grade	1st Grade	159	47.0
	2nd Grade	179	53.0

Note. N = 338 for each group.

Descriptive Statistics and Data Screening

Scores for the continuous variables of interest were calculated by subtracting the post-intervention scores from the pre-intervention scores. The scaled math score difference ranged from -106 to 416 (M = 94.61, SD = 62.60). The student working memory (SWM) difference ranged from -3.14 to 6.37 (M = 0.86, SD = 1.57).

The data were screened for normality with skewness and kurtosis statistics, the Shapiro-Wilk Test of Normality, and histograms. In SPSS, distributions are normal if the absolute values of their skewness and kurtosis statistics are less than two times their standard errors (George & Mallery, 2010). Based on the skewness and kurtosis statistics, the scaled math score difference distribution was not normal. Descriptive statistics for the scaled math scores differences are presented in Table 7.

Table 7

Descriptive Statistics for Difference in Scaled Math Scores

Scaled Math Score Difference		Statistic	Std. Error
Mean		94.61	3.41
95% Confidence Interval for Mean	Lower Bound	87.91	
	Upper Bound	101.30	
5% Trimmed Mean		92.56	
Median		90.50	
Variance		3,918.10	
Std. Deviation		62.59	
Minimum		-106	
Maximum		416	
Range		522	
Interquartile Range		74	
Skewness		0.76	0.13
Kurtosis		3.22	0.27

The Shapiro-Wilk Test of Normality compares the observed distribution to a theoretical normal distribution. If the result is statistically significant, the distribution is not normal. The Shapiro-Wilk Test of Normality indicated that the distribution was not normal ($p < .001$). The skewness was 5.70 times the standard error. The kurtosis was 12.15 times the standard error. The histogram for the scaled math scores difference is presented in Figure 8.

Figure 8. *Histogram for difference in scaled math scores.*

Next, the distribution was screened for statistical outliers with box and whisker plots. Statistical outliers are indicated as points above or below the whiskers in a box and whisker plot. They are determined to fall below Q1-1.5 times the interquartile range (IQR) or above Q3 + 1.5* the interquartile range. For the difference in scaled math scores, the median was 90.50. The IQR was 74. There were 11 statistical outliers. Four are less than or equal to negative 60, and seven are greater than or equal to 243. The box and whisker plot for the difference in scaled math scores is presented in Figure 9.

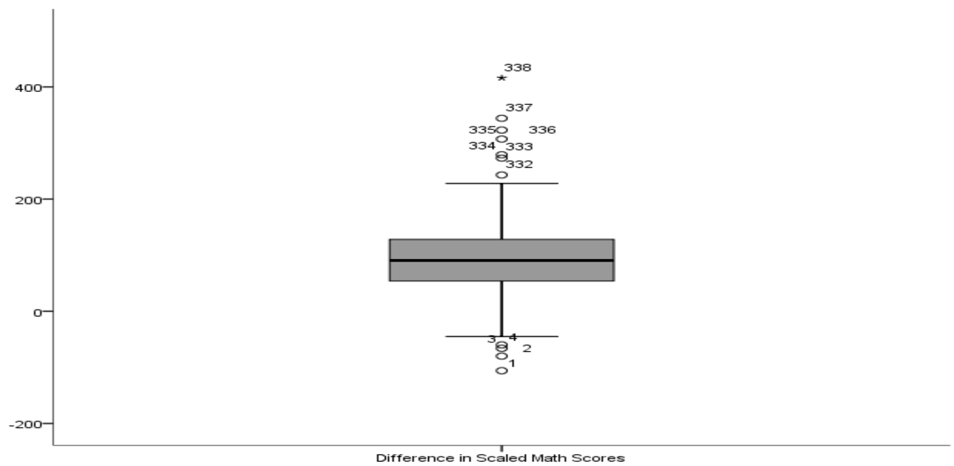

Figure 9. Box and whisker plot for difference in scaled math scores.

No statistical outliers were removed from the data as it was assumed that the tests were correctly scored.

The same process was followed for the difference in SWM scores. Based on the skewness and kurtosis statistics, the distribution for the SWM difference was normal. Descriptive statistics for the SWM are presented in Table 8.

Table 8

Descriptive Statistics for Difference in Student Working Memory Scores

Student Working Memory Difference		Statistic	Std. Error
Mean		.857	.124
95% Confidence Interval for Mean	Lower Bound	.612	
	Upper Bound	1.10	
5% Trimmed Mean		0.85	
Median		0.80	
Variance		2.46	
Std. Deviation		1.57	
Minimum		-3.14	
Maximum		6.37	
Range		9.51	
Interquartile Range		1.75	
Skewness		.216	.192
Kurtosis		.677	.383

The Shapiro-Wilk Test of Normality indicated that the distribution was normal and not statistically significant (p = .213). The skewness was 1.13 times the standard error. The kurtosis was 1.77 times the standard error. The histogram for the difference in student working memory scores is presented in Figure 10.

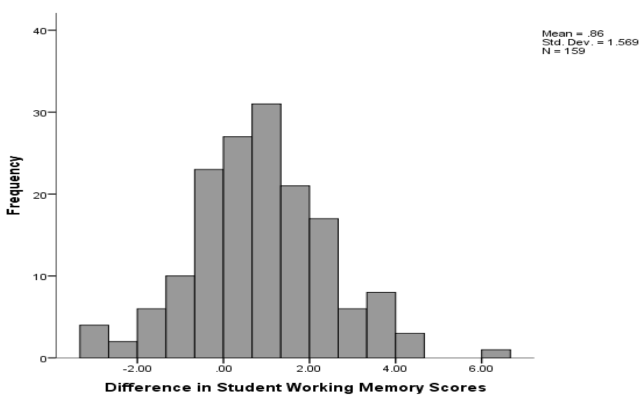

Figure 10. Histogram of the difference in student working memory scores.

For the difference in student working memory scores, the median was 0.80. The IQR was 1.75. There were six statistical outliers; four were less than or equal to -2 7/10, and two were greater than or equal to 4 6/10. The box and whisker plot for the difference in student working memory scores is presented in Figure 11.

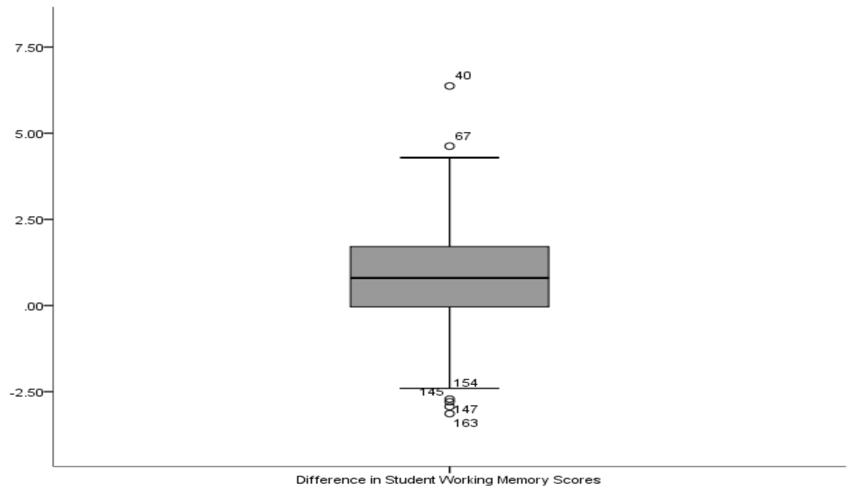

Figure 11. Box and whisker plot for difference in student working memory scores.

No statistical outliers were removed from the data as it was assumed that the tests were correctly scored.

Research Questions and Hypothesis Testing

Research Question One

Research question one asked, "Does implementing the abacus curriculum improve the overall mathematics achievement of 1st and 2nd grades as measured by the STAR assessment diagnostic achievement test?" This research question was tested with two independent samples t-tests as there were two associated null hypotheses. The first hypothesis was tested using the difference in math scores from students in the 1st grade, which was the dependent variable. The independent variable was abacus status with two levels (yes versus no). Group means for the difference in math scores by abacus status for students in the 1st grade are presented in Table 9.

Table 9

Group Means for Difference in Math Score by Abacus Status for 1st graders

	Abacus	n	M	SD	Std. Error Mean
Math Score Difference	No	59	105.64	90.17	11.74
	Yes	100	102.10	54.91	5.49

T-test results for the comparison are presented in Table 10.

Table 10

T-Test Results for Difference in Math Score by Abacus Status for 1st graders

		t	df	p	Mean Difference
Math Score Difference		0.308	157	.758	3.54

There was no statistically significant difference between the overall pre and post mean scores for 1st graders who were exposed to the abacus (M = 102.10, SD = 54.91) versus those who were not (M = 105.64, SD = 90.17), t(157) = 0.31, p = .758, two-tailed. Therefore, the null hypothesis was not rejected. See Figure 12.

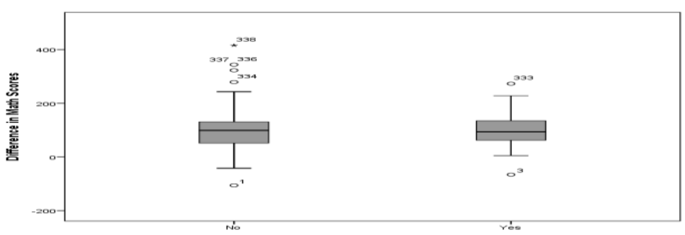

Figure 12. Group means for difference in math score by Abacus status for 1st graders.

The second hypothesis was tested using the difference in math scores from students in the 2nd grade, which was the dependent variable. The independent variable was abacus status with two levels (yes versus no). Group means for the difference in math scores by abacus status for students in the 1st grade are presented in Table 11.

Table 11

Group Means for Difference in Math Score by Abacus Status for 2nd Graders

	Abacus	n	M	SD	Std. Error Mean
Math Score Difference	No	104	83.54	60.18	5.90
	Yes	75	91.28	45.16	5.21

T-test results for the comparison are presented in Table 12.

Table 12

T-Test Results for Difference in Math Score by Abacus Status for 2nd Graders

		t	df	p	Mean Difference
Math Score Difference		-0.939	177	.349	-7.74

There was no statistically significant difference between the overall pre and post mean scores for 2nd graders who were exposed to the abacus (M = 91.28, SD = 45.16) versus those who were not (M = 83.54, SD = 60.18), t(177) = -0.94, p = .349, two-tailed. Therefore, the null hypothesis was not rejected. See Figure 13.

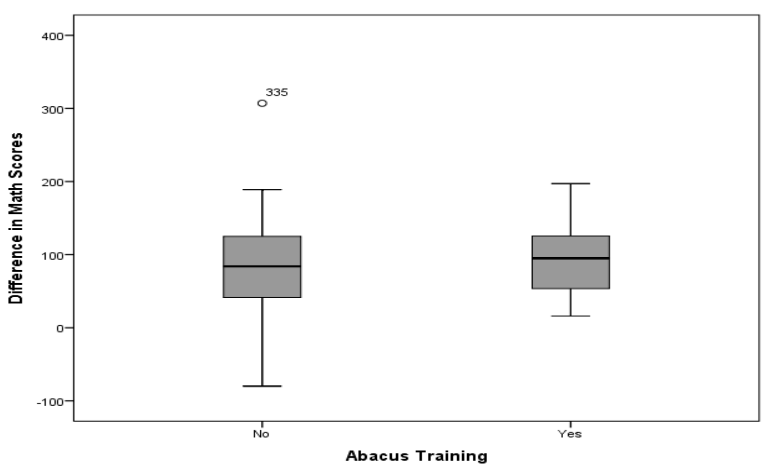

Figure 13. Group means for difference in math score by Abacus status for 2nd graders.

Research Question Two

Research question two asked, “How do physical abacus and mental abacus use affect the assessment scores of 1st graders versus 2nd graders?” Research question 2 was tested with an independent sample t-test. The dependent variable was the difference in math scores among students with physical and mental abacus training. The independent variable was grade status (1st versus 2nd grade). Group means for the difference in math scores among students who had physical and mental abacus training by grade are presented in Table 13.

Table 13

Group Means for Difference in Math Scores among Students with Abacus Training by Grade Level

	Grade	n	M	SD	Std. Error Mean
Math Score Difference	1st Grade	100	102.10	54.91	5.49
	2nd Grade	75	91.28	45.16	5.21

T-test results for the comparison are presented in Table 14.

Table 14

T-Test Results for Difference in Math Scores among Students with Abacus Training by Grade Level

		t	df	p	Mean Difference
Math Score Difference		1.39	173	.166	10.82

There was no statistically significant difference between the overall pre and post mean scores for 1st graders who were exposed to the abacus (M = 102.10, SD = 54.91) versus 2nd graders who were exposed to the abacus training (M = 91.28, SD = 45.16), t(173) = 1.39, p = .166, two-tailed. Therefore, the null hypothesis was not rejected. See Figure 14.

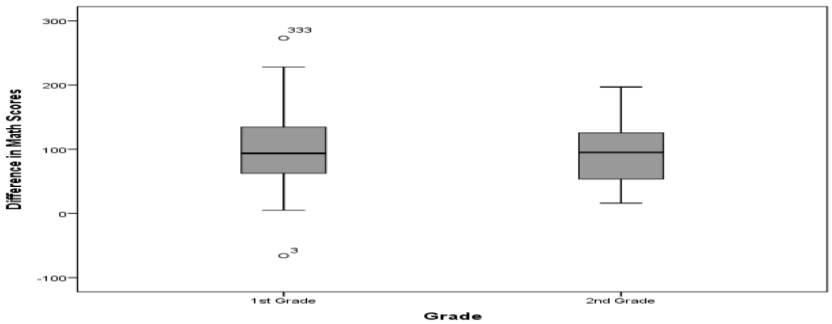

Figure 14. Group means for difference in math scores among students with Abacus training by grade level.

Research Question Three

Research question three asked, “Is there a significant difference in the growth in mathematics test scores of students who underwent the abacus training as compared to students in the control group, and does grade level affect the outcomes?” Research question 3 was tested with a two-way ANOVA. The dependent variable was the difference in math scores. The independent variables were abacus status (control group versus abacus training group) and grade level (1st versus 2nd grade). Group means for the difference in math scores by abacus status and grade level are presented in Table 15.

Table 15

Group Means for Difference in Math Scores by Abacus Status and Grade Level

Abacus	Grade	M	SD	n
No	1st Grade	105.64	90.17	59
	2nd Grade	83.54	60.18	104
	Total	91.54	72.99	163
Yes	1st Grade	102.10	54.91	100
	2nd Grade	91.28	45.16	75
	Total	97.46	51.10	175
Total	1st Grade	103.42	69.84	159
	2nd Grade	86.78	54.39	179
	Total	94.61	62.59	338

The ANOVA summary is presented in Table 16.

Table 16

ANOVA Summary Table for Difference in Math Scores by Abacus Status and Grade Level

Source	df	Mean Square	F	p	Partial η^2	Observed Power
Abacus	1	353.10	0.09	.763	.00	.06
Grade	1	21726.29	5.61	.018	.02	.66
Abacus * Grade	1	2552.51	0.66	.418	.00	.13
Error	334	3874.33				
Total	337					

There was no main effect for abacus status, F(1, 334) = 0.09, p = .763, η^2 = .0, observed power = .06. Therefore, the null hypothesis was not rejected. There was a main effect for grade level F(1, 334) = 5.61, p = .018, η^2 = .02, observed power = .66. Therefore, the null hypothesis was rejected. The interaction was not statistically significant, F(1, 334) = 0.66, p = .418, η^2 = 0, observed power = .13. Therefore, the null hypothesis was not rejected. See Figure 15.

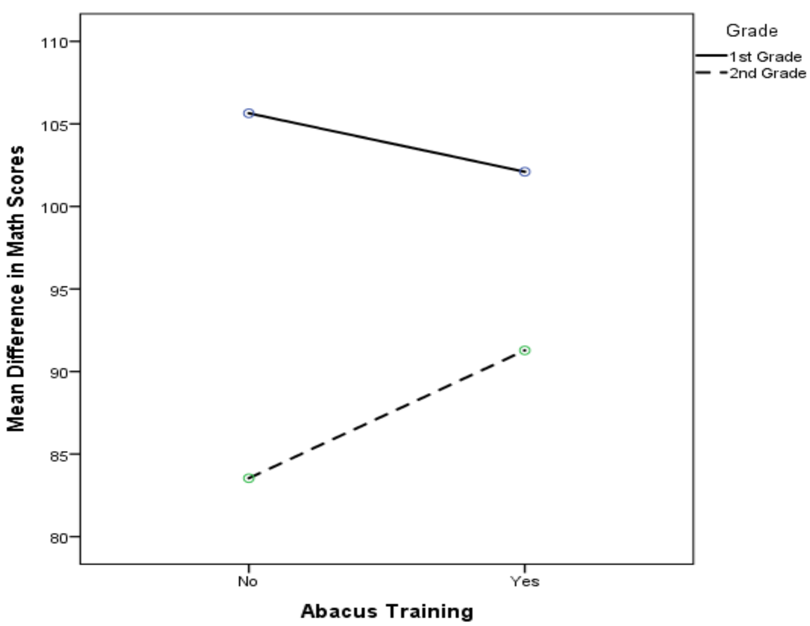

Figure 15. Line graph of difference in math scores by Abacus status and grade level.

Research Question Four

Research question four asked, “Does mental abacus improve students’ working memory?” Research question 4 was tested with a two-way ANOVA. The dependent variable was the difference in student working memory scores. The independent variables were abacus status (control group versus abacus training group) and grade level (1st versus 2nd grade). Group means for the difference in student working memory scores by abacus status and grade level are presented in Table 17.

Table 17

Group Means for Difference in Student Working Memory Scores by Abacus Status and Grade Level

Group	Grade	M	SD	n
Control	1st Grade	0.86	1.53	25
	2nd Grade	0.76	1.86	44
	Total	0.80	1.74	69
Mental Abacus	1st Grade	1.04	1.63	32
	2nd Grade	0.83	1.32	58
	Total	0.90	1.43	90
Total	1st Grade	0.96	1.58	57
	2nd Grade	0.80	1.57	102
	Total	0.86	1.57	159

The ANOVA Summary Table is presented in Table 18.

Table 18

ANOVA Summary Table for Difference in Student Working Memory Scores by Abacus Status and Grade Level

Source	df	Mean Square	F	p	Partial η^2	Observed Power
Group	1	0.54	0.22	.642	.00	.07
Grade	1	0.89	0.36	.552	.00	.09
Group * Grade	1	0.09	0.04	.846	.00	.05
Error	155	2.50				
Total	158					

There was no main effect for group status, F(1, 155) = 0.22, p = .642, η^2 = 0, observed power = .07.Therefore, the null hypothesis was not rejected. There was no main effect for grade level, F(1, 155) = 0.36, p = .552, η^2 = 0, observed power = .09. Therefore, the null hypothesis was not rejected. There was no significant interaction, F(1, 155) = 0.04, p = .846, η^2 = 0, observed power = .05. Therefore, the null hypothesis was not rejected. See Figure 16.

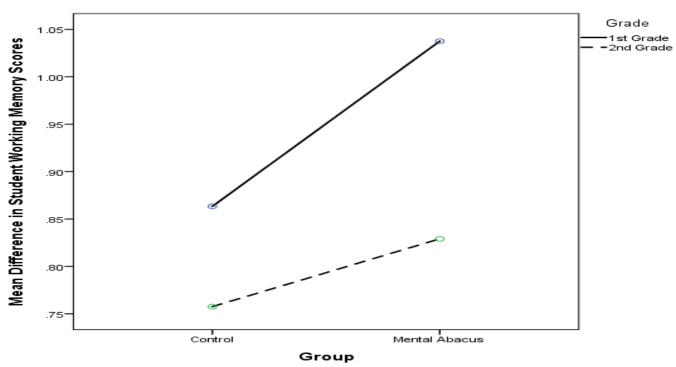

Figure 16. Line graph of group means for difference in student working memory scores by Abacus status and grade level.

Research Question Five

Research question five asked, "Is there a statistically significant difference in male students versus female students' math growth scores who were exposed to the physical/mental abacus training?" Research question 5 was tested with an independent samples t-test. The dependent variable was the difference in student math scores. The independent variable was gender (male versus female). The subsample consisted of only students who were exposed to the physical/mental abacus training. Group means for the difference in math scores by gender are presented in Table 19.

Table 19

Group Means for Difference in Math Scores by Gender among Students Exposed to Abacus Training

	Gender	n	M	SD	Std. Error Mean
Difference in Math Scores	Female	70	88.69	53.89	6.44
	Male	105	103.31	48.54	4.74

T-test results for the comparison are presented in Table 20.

Table 20

T-Test Results for Difference in Math Scores by Gender among Students Exposed to Abacus Training

		t	df	p	Mean Difference
Math Score Difference		-1.87	173	.063	-14.63

There was no statistically significant difference between the math growth scores for males who were exposed to the abacus (M = 103.31, SD = 48.54) training versus females who were exposed to the abacus training (M = 88.69, SD = 53.89), t(172) = -1.87, p = .063, two-tailed. Therefore, the null hypothesis was not rejected. The hypotheses and outcomes are summarized in Table 21.

Table 21

Hypothesis Summary and Outcomes

Hypothesis	Statistical Test	Significance	Outcome
H_{01}a: There is no significant difference between the overall pre- and post-mean scores for 1st graders who were exposed to the abacus versus those who were not.	Independent Samples t-test	p = .758	Null Not Rejected.
H_{01}b: There is no significant difference between the overall pre- and post-mean scores for 2nd graders exposed to the abacus versus those who were not.	Independent Samples t-test	p = .349	Null Not Rejected.
H_{02}a: There is no significant difference between the pre- and post-growth scores for 1st graders versus 2nd graders.	Independent Samples t-test	p = .166	Null Not Rejected.
H_{03}a: There is not an interaction between grade level and participation in abacus training.	Two-Way ANOVA	p = .418	Null Not Rejected.
H_{03}b: There is no difference in the growth for the different grade level STAR scores.	Two-Way ANOVA	p = .018	Null Rejected.
H_{03}c: There is no difference for students in abacus and control groups.	Two-Way ANOVA	p = .763	Null Not Rejected.
H_{04}a: There is not an interaction between grade level and participation in abacus training on working memory.	Two-Way ANOVA	p = .846	Null Not Rejected.
H_{04}b: There is no difference in the growth for the different grade level scores	Two-Way ANOVA	p = .552	Null Not Rejected.
H_{04}c: There is no difference for students in abacus and control groups.	Two-Way ANOVA	p = .642	Null Not Rejected.
H_{05}a: There is no significant difference in male students' versus female students' math growth scores exposed to the physical/mental abacus training.	Independent Samples t-test	p = .063	Null Not Rejected.

Summary

Five research questions and ten associated hypotheses were formulated for investigation. One significant result was observed. Implementing the abacus curriculum did not significantly improve the overall mathematics achievement of 1st and 2nd graders as measured by the STAR assessment diagnostic achievement test. Among 1st and 2nd graders who received physical and mental abacus training, there was no statistically significant difference in the math assessment scores of 1st graders versus 2nd graders.

In addition, there was no statistically significant difference in the growth in mathematics test scores of students who underwent the abacus training compared to students in the control group, and grade level did not significantly affect the outcomes. The mental abacus did not significantly improve students' working memory. There was no statistically significant difference in male students' versus female students' math growth when exposed to physical/mental abacus training. However, math scores were significantly higher for students in the 1st grade versus students in the 2nd grade independent of abacus training. Moreover, math growth scores for 1st-grade students declined slightly for the abacus group compared to those who did not receive abacus training. Conversely, math growth scores for 2nd graders improved slightly in the abacus group compared to the group that did not receive abacus training. Implications and recommendations will be discussed in Chapter 5.

CHAPTER 5

DISCUSSION

In the United States, greater emphasis has to be placed on the math curriculum and the methods used to deliver mathematical instruction. The method of utilizing abstract styles to teach fundamental mathematical concepts has worked for some. However, research and data indicate that the United States lags behind many countries in mathematical performance. The use of an abacus to help students is utilized in many high-performing countries, like Singapore, parts of India, parts of Africa, and China. The use of a physical abacus and the transference of those hard skills to a mental image or Mental Abacus (MA)-the technique of performing fast, accurate arithmetic using a mental image of an abacus (Barner, 2016), have been used as a manipulative to help support student learning.

A 1-year study was conducted by Barner and Frank (2016) to investigate the possibility of utilizing the mental abacus as a manipulative to support mathematical instruction. Subsets of the data from the original study were analyzed in this archival study to explore the claim outlined by Vygotsky, who believed that the wherewithal for intellectual development and adaptation in children is innate (Vygotsky, 1978). While children may develop higher mental functioning through MA, this was not supported by the 1-year study.

Researchers like Hatano et al. (1978) supported Vygotsky's work and indicated that students exposed to the abacus skills could transfer to learned tasks. However, this claim was not supported for any of the research questions. The results indicate no statistical difference in the scores of the dependent variables in the study. Five research questions were evaluated, and there were no measurable gains in the students' performance on the post math assessment or working memory measure.

For the first research question, does implementing the abacus curriculum improve the overall mathematics achievement of 1st and 2nd grades as measured by the STAR Assessment diagnostic achievement test, the null was not retained. There was no significant difference between the overall pre and post means scores for the students exposed to the abacus versus those not exposed to the abacus. In mathematics, concepts for younger learners usually begin more generally and become more differentiated as they are exposed to different content (Harter, 1983). There were no significant differences between the students in the 2nd-grade students' overall pre- and post-mean scores. One would think their post scores may have been affected because the 2nd graders were a little older and had more exposure to the math standards or content. However, the data did not support the thought between the two grades' post scores. There appeared to be no gains between grades based on the overall post-test scores. The cognitive development of the two groups studied yielded no major improvements in the pre- and post-standardized assessments.

The second research question inquired about any significant differences in mathematics test scores between 1st- and 2nd-grade students who underwent the abacus training. This question focused its attention on the students who underwent the abacus training lessons. The results indicate no statistically significant differences between the test scores of both the 1st- and 2nd-grade students who were subjected to the mental abacus training. Even though for many children around the world, the use of the abacus is utilized as a supplementary tool that yielded significant results for them (Barner & Frank, 2016), the utilization of the apparatus did not support the findings that indicate the increase in student’s performance as a result (Stigler et al., 1986). The thought that mental computation and flexible thinking skills, and number sense would all be impacted by the training (Reys, 1985; Reys & Barger, 1994) was not supported.

While these researchers found that students who mastered the mental computation tool or Mental Abacus increased their basic math computation and problem-solving skills, the participants in this study showed no significant gains on the STAR Assessment according to the analyzed data. These results contrast to previous studies with older participants who learned the mental abacus for a longer duration.

A deeper dive into the research prompted the exploration of differences in the growth in mathematics test scores of students who underwent the abacus training compared to those who were not exposed and their different grade levels. For research question 3, the results of the analyses do not reveal any major differentiation within each of the constructs. The competencies of both grades of students with and without the extensive mental abacus training yielded the same results. There were no main effects for either group of students and either grade level. The research suggests that performance in mathematics is tied to the student's self-concept and their exposure to different activities in life (Harter, 1983). The result of the analyzed data seems to align with the findings of Harter and Pike (1984), who indicated that a child's mathematical skills are pretty general in the formative years. They noted that as children get older, they become more cognitively aware of differentiated mathematical concepts.

In reviewing the grade-specific standards outlined by the state department of education, the focus for 1st grade was to develop an understanding of specific mathematical concepts like addition, and subtraction, developing an understanding of the relationship between whole numbers and place values, and grouping in the tens and ones place. The 2nd grade standards continued to build on the basic concepts taught in 1st grade, emphasizing the understanding of basic ten notations and continued fluency with numbers. These learning standards are grouped for the first two grades.

According to the NJ State Learning Standards, mathematical education's differentiation or major shift occurs in higher grades. Based on the theoretical grouping of the standards, it supports the findings that there would not be much difference in the performance of the 1st versus 2nd grades assessment scores overall. While the data support this notion, the expectation would be that the major differentiation in the results would have been more pronounced with the independent variables (the students exposed to the mental abacus training versus those who did not have it between and among the grade levels). How well students grasp these concepts in the standards will determine how strong their mathematical foundation will be. The building block of the student's journey to learn math begins here. The hope would be that students will find ways and manipulatives to help them internalize the concepts. Part of the discussion researchers explored was how 1st and 2nd graders can understand the contents of the standard taught (Clements & Sarama, 2014). While some have found noticeable differences between the math performances of 1st- and 2nd-grade students (Keller, 2014), this study indicated otherwise. It showed no major differences between the mathematical growth scores of the young scholars, and the result did not change when the mental abacus manipulative was added to the equation. Children exposed to the training improved their math computation and working memory skills (Barner & Frank, 2017).

Researchers such as Klingberg (2010) claimed that one of the major benefits of learning the abacus/mental abacus is the notion that it enhances children's ability to problem-solve, their overall mathematical performance, and their reading ability. In his research, Klingberg found that if young children received consistent training with a mental abacus, the part of the brain that controls the processing of motor and visuospatial abilities improves. The researcher even claimed that students exposed to the training performed computation skills faster and more accurately than their counterparts. He also indicated that the children exposed to the abacus training might acquire the ability to think critically and logically.

The data collected and evaluated on the students in the study working memory did not support the previous researcher’s findings. Research question four inquired as to if mental abacus improved students’ working memory. In analyzing the data, it was determined that there was no significant difference in the working memory scores of the students who were not exposed to the mental abacus training versus those in the 1st and 2nd grades.

The students in this study were exposed to the mental abacus training for a year, while the other students in Klingberg’s and Buschkuchl’s study had several years of extensive training. While the students did not have the same exposure to the mental abacus training, they were exposed to the material for a year. Klingberg’s statement—“Students may acquire gains in their thinking abilities, problem-solving skills, and visuospatial processing—gave the impression that some gains would have been noted in the study. While this study’s approach was not multifaceted in its use of a more intensive means of assessing the student’s gains, the overall results indicated no significant changes or effects of the student’s performance on their overall scale scores on the STAR Math assessments.

Like Hu et al. (2011), other researchers claimed that the way the brain functions in children is positively influenced by using a mental abacus. Furthermore, they concluded that exposure to the mental abacus training saw an increase in brain functioning, enabling students to perform mental computations faster than their counterparts after exposure to the abacus for 3 years or more.

Other researchers on the mental abacus, like Wang et al. (2013), provided evidence that supported the notion that students exposed to mental abacus training would complete numerical tasks at a more rapid rate than those students who did not receive the training. While Wang's research measured the speed and accuracy of the students performing specific mathematical skills, this study did not. The focus of the question dealt mainly with the overall working memory of the students involved in the study. The raw data of this study had a few outliers whose scores were off the chart in terms of growth over the year. Even though the outlier scores were included in the data analyses, they did not impact the overall outcome. The results indicated that there were no significant differences in the tabulated results.

The results were surprising to this researcher. While major changes were not expected in scores with the 1st graders because of their new exposure to the mathematical concepts and where they were developmentally, some impact on the scores of the 2nd graders was expected. The 2nd graders had some acquaintance with the mathematical standards material for an entire year as 1st graders. These standards are basically the same for 2nd grade, with the difference being an expansion of the base ten system. This expansion includes using their understanding to develop fluency with addition and subtraction, understanding place value, and using that understanding to perform the addition and subtraction operations. The 2nd-grade students were exposed to these standards the year before.

Harter's research supported the findings in this study. The results suggested no differentiation in young children's overall math scores even when they were exposed to the mental abacus training. It was expected that the prior knowledge and prior exposure to the mathematical concepts taught in the standard would have helped them internalize and conceptualize the mental abacus strategies taught. Clements and Sarama's (2014) research about how well students understand mathematical concepts in the early grades may have contributed to the lack of differences in the students' performance on the assessment even after exposure to the mental abacus training. Harter's (1982) research about the child's perception of their performances impacting their actual performance had me hopeful that students' scores would have been higher due to their perceived notion of being familiar with the standards taught in 1st grade. Keller's (2014) research, which supports the thought that children are capable of exceeding the expectations of adults, also contributed to my expectations that students' scores would have been positively affected through the mental abacus program. However, this theory was not the focus of the study.

The final research question dealt with gender. The inquiry revolved around the difference between male and female students' math growth scores when exposed to mental abacus training. Studying the topic of gender equity in math and the stereotypes surrounding the performance of male and female students in mathematics stems back years. Heider's 1946 study dealing with cognitive balance deals with the inconsistencies as it relates to gender can be applied to the notion that "math is for boys and I'm a girl, so math is not for me" stereotype. While people in the United States believed that mathematics is a male-dominated content area, this research did not support that notion.

Nosek et al.'s (2002) research found that younger girls, as early as 1st grade perform lower than boys in mathematics, was not supported. There was also no significant difference in math scores between the genders. The p score of .089 supports the notion that there were no statistically significant differences. Based on the outcome of the analyzed data, Cvencek, Greenwald, & Meltzoff's 2011 research, which focused on American elementary school children's performance in math, suggested that boys and girls performed equally on achievement tests in the lower grades. This research was supported in the findings of this study. The male students exposed to the abacus training did not perform at a higher rate than the female students enrolled in the mental abacus program in both 1st and 2nd grade.

The mental abacus study conducted in Singaporean children by Steele (2003), a country that leads the nation in math performance, supported the notion that there was not much gender differentiation in the performance of male versus female students. Both groups performed relatively similarly in math performance assessments and defied the male-dominated stereotype as they grew older, with girls outperforming boys in mathematics. Thus, implicit or explicit biases were not a factor in the math achievement of the participants in this study, contrary to Cvencek et al. (2011).

Marsh et al.'s (1991) finding that the male self-concept of their performance in math usually is higher than that of females and that they tend to score higher on math assessments and math-oriented skills, not supported. The results did not support the notion that 1st-grade boys outperformed 1st-grade girls and 2nd-grade boys outperformed 2nd-grade girls. Instead, both genders among both grades performed relatively similarly on the math assessment after being exposed to the mental abacus program.

Limitations of the Study

In the research examined on the performance of mental abacus with elementary school age children, much of the research was conducted for an extended period. The students were exposed to mental abacus training over 2 years or more. The participants in this study were only exposed to the mental abacus training for a few days each week over a school year, which is the equivalent of approximately ten months. The lack of consistency (for example, students not being exposed daily over the school year) may have contributed to the lack of significance determined in the study.

Another limitation of the study is that the test did not outline specific observations, mathematical concepts, or standards tested during the STAR Assessment. The fact that the assessment was an adaptive test means that other material not studied during the 1st- and 2nd-grade curriculum being taught possibly worked its way into the assessment flow. The students in previous studies exposed to the mental abacus training were assessed on the speed and accuracy of their performances with the abacus and not generalized mathematical concepts. The standards taught by the department of education in 1st and 2nd grades include the following concepts:

1. developing an understanding of addition, subtraction, and the strategies for addition and subtraction within 1 to 20,
2. developing an understanding of whole numbers relating to place value, including grouping into tens and ones,
3. developing the understanding of linear measurement and measuring lengths, as pertaining to length units, and
4. reasoning about attributes of, and composing and decoding, geometric shapes (Schmidt et al., 2009).

Expanding on these same standards for 2nd grade, the assessments should have coincided with these standards without deviating from the topic. Developing an assessment that addressed these specific standards or finding a way to earmark which problems dealt directly with these standards and assessing the students' performance as it related to these standards may have yielded different results.

Another potential impact on the study results is how well the students understood and mastered the abacus and transferred the knowledge into an actual mathematical numerical representation. If the students struggled with the transfer of knowledge between the physical abacus, translating it to a mental abacus, and then ascribing a numerical understanding of the information, then there would be a disconnect, if you will, with the mastery of the mental abacus skill. It would be essential to ensure that students mastered the basics of the mathematical content standards to apply the concept. The age group of the students may have impacted the results.

A final limitation of this study was the teachers' training on how to deliver the instruction to the students. The teachers would learn a concept before teaching the concept. The teachers did not have much time to practice and master the concepts before teaching them. While Master Lee was available to the teachers as a resource, she was not able to consistently oversee the teachers' performance. Future studies should ensure that teachers are thoroughly trained in the skills before teaching. Teachers should be allowed to work through the concepts with each other in the presence of the Abacus Master, delivering the professional development, giving them the luxury of exploration, practice, and comfortability with the material before teaching it. This concept is new to teachers in the United States, and if the material is to be taught with fidelity, then time, money, and training need to be implemented with the teachers involved (Barner et al. 2016; Stigler et al., 1986).

Future Study

First, even though the study results did not support or indicate improvement in mathematical performance or working memory, it is recommended that future studies be conducted with some modifications. This program requires background knowledge and integration of math facts, number representation, and some working knowledge of the standards outlined in the early grades. A future study should be more of a longitudinal study with older students (2nd grade and higher) with the interventions lasting two or more years. The study needs to be conducted with the control group receiving the district's curriculum while the experimental group focuses solely on learning the physical abacus and practicing the mental abacus application.

Second, the intensity of the teacher training has to be modified. In many instances, the teachers received training about a concept a day before teaching the process to students. Teachers who were uncomfortable with the material did not have adequate time to grapple with and establish a comfort level with the topic before attempting to teach it. While the teacher had the mentorship of Master Lee, her time supervision pedagogy was not consistently focused on one teacher or classroom. The time was spent moving through different classrooms throughout the time frame allotted for the mathematical block. It is recommended that more time on task be offered for the teacher to get comfortable enough with the material to teach it with fidelity. Third, the mode of assessing the students' performance should be different. The use of multiple assessments that focus on specific standards of mathematics would have been more useful. The STAR assessment was an adaptive test that assessed multiple standards of mathematics. Future researchers should find an assessment that directly measures the concepts being taught (addition/subtraction/place value/etc.) This would have been a more accurate means of measuring the student's progress. A fourth possibility for future study could look at other variables that could impact a student's performance. For example, topics like a student's math confidence level or a student's perception of how they perform in math could contribute to the study outcome.

Finally, a future study could focus on how the mental abacus affects students with behavioral challenges. It was observable that students who had difficulties sitting, challenges following instructions, and struggled to remain in a classroom could focus and engage fully in the mental abacus program. Why was this program appealing to them? Was class size a factor? Several questions are left to be answered, and it is anticipated that future studies will help fill in the missing pieces.

Recommendations for practice/Implications for School

A small group of 10 students was observed in a summer abacus intensive program at the end of 2nd grade. Those students were then placed in the abacus program in 3rd grade and received the instruction along with the other students involved in the program. They also received two additional hours with Master Lee three times a day. At the end of the school year, those 10 students could add and subtract strings of 3 numbers at an incredible speed. These students did not have any significant outbursts during the program. They listened intently when Master Lee dictated at a whisper. The students quieted down and listened intently to garner the information. It would be interesting to examine whether the mental abacus program could help students overcome attention/behavioral challenges.

The researcher believes there is merit to past research conducted with the abacus program. In light of the difficulties our students across the nation are having performing at proficient and advanced proficiencies on state assessments (NJDOE, 2016), it is worth trying other manipulatives that will help support students in their mathematical learning. The abacus/mental abacus program is a viable means of doing so.

I recommend that school leaders utilize the abacus/mental abacus tool in the upper grades and introduce the apparatus in the 2nd grade when students have been exposed to the concepts of place value and other strands taught by the learning standards. Another recommendation would be that the manipulative is used consistently for multi-year efforts and not as a standalone introductory concept.

Conclusion

Students in the United States of America continue to lag behind other countries in its mathematical performance. While hundreds of math programs are introduced to students in hopes of raising their math performance, students across the nation continue to struggle, as evident by their assessment scores. Researchers have found that in-depth study of the abacus over 3 years or more appears to yield overall positive results with students exposed consistently.

Students in the United States may yield significant gains in mathematical performances with consistent exposure to physical abacus training. After the students have truly mastered the physical abacus, they should attempt to master the mental abacus training. One pitfall of the math curriculum is often looking to transition students from physical manipulative and concrete concepts to an abstract mathematical concept too soon. If the physical concept is not fully realized, students tend to have difficulty engaging in abstract concepts in mathematics (Stigler et al., 1986).

The results of this study on the effects of the mental abacus on 1st- and 2nd-grade standardized test scores indicated that over a year, there were no statistically significant differences between the performances of the control group and the experimental group. While researchers have found that over 2 or more years, there have been significant gains in the performance of students exposed to the mental abacus training, this study was limited to a year. Thus, those findings were not consistent with this study. For each of the research questions, the data indicated no statistically significant impact or differences in the performance of the students exposed to the abacus/mental abacus training as opposed to those who were not exposed.

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APPENDIX A