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Students with visual impairments and math: Impact of practice on achievement and attitude

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Abstract

"Achievement in mathematics among blind and severely visually impaired persons is, and always has been, extraordinarily low" compared to students with sight (Kapperman & Sticken, 2004, p. 1). In fact, according to Kapperman and Sticken, many people who are blind are unable to perform mathematical operations in "real-life" situations, such as calculating change or doubling a recipe. There are many reasons this is so, including the visual nature of math, delayed development of concepts needed to understand math, and lack of necessary knowledge among teachers of students with visual impairments. In this research, the researcher aimed, first, to show that practice will increase math learning in students with visual impairments, and second, to find out whether different practice approaches result in different outcomes. Participants in Part I of this study were six students with visual impairments in the sixth and seventh grades, all of whom where behind their sighted classmates in math. Participants in Part 2 of this study were five students with visual impairments in the fourth, fifth, and sixth grades, all of whom were behind their sighted classmates in math. To test these hypotheses, the researcher met with each student for 30 minutes daily to practice math skills, randomly assigning students to rote practice, multisensory practice, or a combination of the two in Part I, and with the students in Part 2 as a group, for 15 to 45 minutes daily for math skill instruction and rehearsal, and recording observational data to gauge the students' attitudes toward math. Findings indicated that all of these students benefited from extra practice both in math performance and in attitude toward mathematics.

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STUDENTS WITH VISUAL IMPAIRMENTS AND MATH: IMPACT OF PRACTICE ON ACHIEVEMENT AND ATTITUDE

by

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Table of Contents

Abstract

"Achievement in mathematics among blind and severely visually impaired persons is, and always has been, extraordinarily low" compared to students with sight (Kapperman & Sticken, 2004, p. 1). In fact, according to Kapperman and Sticken, many people who are blind are unable to perform mathematical operations in "real-life" situations, such as calculating change or doubling a recipe. There are many reasons this is so, including the visual nature of math, delayed development of concepts needed to understand math, and lack of necessary knowledge among teachers of students with visual impairments. In this research, the researcher aimed, first, to show that practice will increase math learning in students with visual impairments, and second, to find out whether different practice approaches result in different outcomes. Participants in Part 1 of this study were six students with visual impairments in the sixth and seventh grades, all of whom where behind their sighted classmates in math. Participants in Part 2 of this study were five students with visual impairments in the fourth, fifth, and sixth grades, all of whom were behind their sighted classmates in math. To test these hypotheses, the researcher met with each student for 30 minutes daily to practice math skills, randomly assigning students to rote practice, multisensory practice, or a combination of the two in Part 1, and with the students in Part 2 as a group, for 15 to 45 minutes daily for math skill instruction and rehearsal, and recording observational data to gauge the students' attitudes toward math. Findings indicated that all of these students benefited from extra practice both in math performance and in attitude toward mathematics.

Students with Visual Impairments and Math: Impact of Practice on Achievement and Attitude

"Achievement in mathematics among blind and severely visually impaired persons is, and always has been, extraordinarily low" compared to students with sight (Kapperman & Sticken, 2004). In fact, according to Kapperman and Sticken, many people who are blind are unable to perform mathematical operations in "real-life" situations, such as calculating change or doubling a recipe. Kapperman and Sticken (2004) give many reasons why this is so. First, math is a visual discipline. Vocabulary such as direction, quantity, and shape, is based primarily on visual reference (Kapperman & Sticken, 2004; Dick & Kubiak, 1997). Second, students born with visual impairments (congenital visual impairments) are also delayed in developmental areas important to understanding math, including spatial and directional concepts (up, down, here, there, more, less), object permanence, and the conservation of mass and volume (Kapperman & Sticken, 2004; Dick & Kubiak, 1997). Students with severe visual impairments cannot perceive information as a whole like students with sight; they must piece together this information to create the whole (Kapperman, Heinze, & Sticken, 2000). Because of this, math takes more effort for students with visual impairments than fields that are verbal in nature (Kapperman & Sticken, 2004). A final reason listed by Kapperman and Sticken (2004), and also found by DeMario and Lian (2000) is that teachers of students with visual impairments tend to have inadequate training in the Nemeth Code of Braille used for mathematics, and lack enough mathematical or technical knowledge to feel confident assisting students with visual impairments in math. In fact, according to a survey conducted by Rosenblum and Amato (2004), 25% of university instructors feel that their students are not competent in Nemeth code due to limited instructional time.

Mathematics, technology, and science professionals agree that their experiences in school at the K-12 level provided them with the general literacy foundation they needed to be successful once they entered specialized post-secondary courses (Senge, 1998). These professionals agree that having a visual impairment would have had the greatest effect on their ability to succeed in math or science because the visual impairment would negatively affect access to necessary information (Senge, 1998). According to Senge (1998), one of the leading causes of the under-representation of people with visual impairments in math and science is the lack of preparation for higher education during the K-12 years.

According to the American Foundation for the Blind's (AFB) interpretation of the Bureau of Labor Statistics Report, 79% of people with disabilities are not in the labor force (AFB, 2010). This number is much higher than the unemployment rate because the unemployment rate does not include people who are not actively searching for a job, while the category "not in the labor force" does include these people. In the general population, only 30% of people are not in the labor force. Of working-age adults, ages 16-64 with visual impairments, 56% are not in the labor force. According to Kapperman & Sticken (2004), the absence of math skills can lead to reduced or no career options. This assertion appears to be supported by statistics compiled by Viisola (1999) that, three to five years after secondary school, only 29% of students with visual impairments are employed. Fifty-seven percent of people with other disabilities are employed three to five years following secondary school, and 69% of the general population is employed in this same period. Kapperman and Sticken (2004) also point out that low mathematics performance can affect admission into higher education, even if performance in all other subjects is acceptable, because low math sub-scores on tests for admittance to higher education institutions can lower the overall test score.

For a clue into how professionals who work with students with visual impairments can help to decrease these problems, we can turn to brain research to explain how the brain learns and remembers.

When the brain learns, it physically changes; neurons actually swell, sway, and split (Myers, 2005, Medina, 2008). They can stay put and strengthen existing connections (Medina, 2008). Neurons can break connections, move to a new location, and form new connections (Medina, 2008). Information enters the brain, following certain pathways in the brain (Myers, 2005). When activity is increased in a pathway, the neurons either form new connections along this pathway or strengthen existing connections (Myers, 2005, Medina, 2008).

As teachers, we want our students to remember what they are learning. In order to teach in such a way that students retain the learning, we must base our instruction on knowledge of how the brain learns and remembers. There are three levels of memory (Sousa, 2007). Immediate memory lasts for an average of about 30 seconds, which stores information like phone numbers until they are used, after which the memory is discarded (Sousa, 2007; Medina, 2008). Working memory, which lasts longer (minutes or days) holds things that require full conscious thought and attention (Sousa, 2007; Medina, 2008). It is from working memory that items are either discarded after they no longer require our attention, or stored in long-term memory for use when needed (Sousa, 2007;

Medina, 2008). According to Sousa (2007), there is almost no transfer to long-term memory without rehearsal, or practice. Long-term memory is what we, as teachers, want to activate for lifelong recall of the skills and concepts we are teaching. In order to transfer information from immediate to working memory, and eventually to long-term memory, the brain needs constant re-exposure to the information (Medina, 2008; Myers, 2005). Maintenance rehearsal refers to repetition of information and is effective for keeping information in working memory (Medina, 2008). The most powerful way to "fix" a memory in the brain, according to Medina (2008) and Myers (2005), is elaborative repeated exposure in specifically timed intervals.

Medina (2008), Myers (2005), and Sousa (2007) illustrated the need for rehearsal. Sousa (2007), Hannaford (2005), and Medina (2008) all discuss types of rehearsal. The two types of rehearsal the researcher is examining for this project are rote and multisensory rehearsal. Rote rehearsal seems to follow the tenants of maintenance rehearsal explained by Medina (2008). It will keep the information fresh, but Sousa (2007) says that it only allows the brain to store information in a certain order. For things like phone numbers that need to be remembered in order, rote rehearsal is fine. However, Sousa (2007) says that students who memorize mathematical information through rote rehearsal will be able to recall the information, but unable to apply the information in new situations. Medina (2008) agrees with this when he writes about schools and businesses that emphasize rote rehearsal. He states that this type of institution "ignores the improvisatory instincts drilled into us for millions of years" (Medina, 2008, p. 38). Hannaford (2005) states that, because of the large area of the brain involved with the hand, touch plays an important role in cognitive, emotional, linguistic, and psychological development.

As discussed earlier, learning is all about forming and strengthening connections in the brain (Myers, 2005, Medina, 2008). It makes sense, then, to think that the more strong connections one can make in the brain, the more learning there will be. Medina (2008) says, "The more attention the brain pays to a given stimulus, the more elaborately the information will be encoded and retained" (p. 75). In other words, the more of the brain engaged for a particular task or experience, the more connections will be made and the better the learning will be (Medina, 2008). Hannaford (2005) says that hands-on experiences and manipulatives increase learning efficiency. Multisensory rehearsal activates more of the brain, which allows the brain to make connections with prior learning (Hannaford, 2005). These connections allow the brain to apply new learning in diverse situations (Sousa, 2007; Hannaford, 2005).

There has been much research about multisensory rehearsal. First, we must understand how our brain creates declarative memories. This is a process involving four steps: encoding, storing, retrieving, and forgetting (Medina, 2008, Myers, 2005). Forgetting allows us to prioritize (Medina, 2008). If we were not able to forget, Medina (2008) demonstrates through a case study, we would be unable to function. Medina (2008) explains that, because of the way our brain encodes information, we store parts of information all over our brains. Counter-intuitively, the more areas of our brain over which the information is scattered, the more robust retrieval will be (Medina, 2008).

Encoding is what we, as teachers, can best facilitate. All of the senses are involved in encoding (Medina, 2008). With every experience one has, information from all senses is transported to the sensory processing areas scattered throughout the brain (Medina, 2008). According to Medina (2008), the more elaborately information is encoded, meaning the more senses involved, the better one's recall of the information will be.

Citing multiple studies, Medina (2008) demonstrates that our senses are designed to work together. Even in cases in which the brain is mis-wired, the senses work together (Medina, 2008). People who have a neurological disorder called Synesthesia experience two senses at once, such as a color associated with a number or a taste with a sound (Medina, 2008). It has been shown that these people often have an unusually good memory (Medina, 2008).

A couple of other studies have shown that when presented certain sensory information, other sensory areas in the brain will be activated (Medina, 2008). In one study, the researchers demonstrated that when shown a video of a person speaking, but without audio, the auditory cortex in the brain was activated, but only when the movements on the video were related to speech (Medina, 2008). A second study paired flashing lights with intermittent tactile stimulation. After a time, the tactile processing center was activated with the visual cortex when the lights flashed (Medina, 2008).

The previous information pertains to how a typical brain learns. A visual impairment, however, has a significant impact on the encoding process. As stated before, encoding involves all of the senses (Medina, 2008). However, not all of the senses have an equal share in the brain's processing of information. Vision is our dominant sense (Medina, 2008, Myers, 2005). According to Medina (2008), "vision is the best tool we have for learning" (p. 233). He explains, through the use of case studies, that the more visual the information can be made, the more likely it is to be recalled (Medina, 2008). In fact, "more of our brain is devoted to vision than to any other sense" (Myers, 2005, p. 156). Students with visual impairments lose much or all of either the visual input or the ability to process this input. Because math is a primarily visual field (Kapperman & Sticken, 2004), this makes math incredibly difficult for students with visual impairments.

Research Questions & Hypotheses

It is generally accepted in American culture that practice leads to mastery. Musicians and athletes practice regularly to hone their skills. A common phrase, "practice makes perfect", illustrates this attitude. In school, students often practice new skills through worksheets, projects, and homework assignments. In mathematics, especially, sighted students use many methods to practice skills, such as flash cards, memorization techniques, repetition, worksheets, and more. Brain research (Myers, 2005, Medina, 2008, Hannaford, 2005, Sousa, 2007) supports this practice. Students with visual impairments need rehearsal just as much as students with sight. The purposes of this research project are, first, to show that practice will increase math learning and positive attitudes toward math in students with visual impairments, and second, to find out whether different practice approaches result in different outcomes. The researcher hypothesizes, based on research done by Myers (2005), Medina (2008), Hannaford (2005), and Sousa (2007), that any type of practice will enhance math learning in students with visual impairments, and that compared to other practice approaches, rote rehearsal will generate the least amount of effectiveness, both in mathematics performance and attitude toward mathematics.

Part 1

Participants

To test these hypotheses, the researcher designed a research project based on a pre-test/post-test comparison and observational data. The participants in the research in this case are six students, five in the sixth grade, and one in the seventh grade, all of whom have visual impairments of varying severity and all of whom are two to four years behind their sighted classmates in math, based on the Michigan Grade Level Content Expectations. The researcher's faculty advisor has a professional relationship with the teacher of students with visual impairments in the school that these students attend, and they are all on her caseload. This teacher chose students who fell most behind their sighted classmates with the hope that math practice would help these students get closer to the mathematics level of their sighted classmates. All students are from the same low-income, urban school located in the Midwest region of the United States.

To protect the identity of the students participating in this research, each student was randomly assigned a number (1-6) using a calculator with a random number generator. Students were also randomly assigned one of three possible practice types: rote rehearsal, multisensory practice, or a combination of the two.

Student 1 has low vision and does not need extensive vision modifications. This student was unable to perform subtraction beyond single-digit memorized tables. The type of practice assigned to this student was a combination of rote rehearsal and multisensory practice.

Student 2 is a Braille reader, requiring alternative methods of accessing mathematics. This student knew the multiplication times tables, but did not know how to multiply double-digit by single-digit numbers beyond ten. This student was assigned rote rehearsal.

Student 3 is a braille reader except in math, where very large print is used. This student was able to multiply double-digit by single-digit numbers, but was unable to multiply two double-digit numbers. This student was assigned rote rehearsal.

Student 4 is able to read print and does not need extensive vision modifications. Like Student 3, this student was able to multiply single-digit by double-digit numbers, but was unable to multiply two double-digit numbers. This student was assigned a combination of rote rehearsal and multisensory practice.

Student 5 is a Braille reader, also requiring alternative methods of accessing mathematics. This student was similar to Student 2 in his/her knowledge of the times tables but had no mathematical knowledge beyond memorized facts. This student was assigned to rote rehearsal.

Student 6 is the most advanced of the group in mathematics. This student has low vision and requires large print. Student 6 had learned some division; single- or double-digit by single digit, in which knowledge of times tables was all that was required. This student did not yet understand long division. This student was assigned to a combination of rote rehearsal and multisensory practice.

Method

Students first took a pre-test in their preferred learning medium (print, large print, Braille, read-aloud, etc.) to find a baseline skill level. The pre-test included skills they had already mastered, as well as skills they had not yet learned, according to the teacher of students with visual impairments. The pre- and post-tests were timed for another level of comparison, but students were told to take as much time as they needed to complete the test. Using the pre-test, the researcher determined what skill the students had difficulty with and practiced this skill one-on-one with the student during the course of the research project. For one month during school days, the researcher met one-on-one with each student for 30 minutes to practice the math skills using the assigned approach. It should be noted that on some days scheduling conflicts prevented the meeting. During this time, the researcher also recorded observations about the students' apparent attitude toward math, including body language, and comments made by the students in the course of normal conversation during these 30 minute practice sessions. At the end of the month, the researcher administered the post-test in the students' preferred learning medium. The post-test was the same as the pre-test so that results could be compared.

The researcher based the focus of the practice with each student on his or her performance on the pre-test. Student 1 would be working on single-digit numbers subtracted from double-digit numbers. Students 2 and 5 would be practicing multiplication of a single-digit number by a double-digit number. Students 3 and 4 would practice multiplying two double-digit numbers, and Student 6 would be practicing long division.

The researcher and students used the standard American algorithm for rote rehearsal. The students assigned to multisensory rehearsal used manipulatives to gain a greater understanding of the mathematical concepts being rehearsed. Strategies and manipulatives used included the National Library of Virtual Manipulatives, Digiblox, tactile multiplication and division problems, and a Brannan Cubarithm slate, among others (see appendix).

Student 1. On the first day of research, the researcher found that Student 1 did not have even a basic understanding of place value. He/she was not aware of what "tens" and "ones" were, let alone what it meant when the researcher asked this student to start in the ones column. Because some of the later activities would involve borrowing or regrouping, the researcher thought it would be important to have this student practice place value. Using Digiblox, the researcher had the student practice making numbers. Soon, a handmade place value mat was introduced and the student practiced making numbers on the place value mat, and identifying tens and ones. Once the student had an understanding of place value, the researcher and student began to practice subtraction by having the student create a number, give the researcher the number of Digiblox asked for, and identifying how much he/she had leftover. Later in the research, the researcher introduced a virtual base-ten manipulative from the National Library of Virtual Manipulatives. The student was able to use the virtual base-ten blocks to solve problems generated by the program. The student used the virtual manipulative to solve the problems on the post-test.

Student 2. This student began with only knowledge of memorized times tables. On the first day, the researcher used Braille flash cards to test the student's knowledge of the times tables, since the student was unable to complete any of the problems on the pre-test. Finding the student had complete knowledge of the times tables, the researcher moved on to use the Brannan Cubarithm Slate to practice the standard American algorithm of multiplication with this student. During the course of the research, this student only practiced single-digit numbers multiplied by double-digit numbers. This student used the Brannan Cubarithm Slate to solve the problems on the post-test.

Student 3. Student 3 was familiar with the standard American algorithm for multiplying a double-digit by a single-digit number. This student was able to read very large print, so problems were written and solved with a marker. During the course of the research, this student practiced multiplying two double-digit numbers together using the standard American algorithm. Each day, the researcher prepared multiple problems, and the student would work the problem on paper, sometimes having to explain the procedure aloud to the researcher.

Student 4. This student was also familiar with the standard American algorithm for multiplying a double-digit number by a single-digit number. This student did not require much vision modification, but was more motivated to practice math problems when using a marker. To practice, this student used a marker on paper and a large-scale model of a multiplication problem. Large numbers were printed on paper and laid out on the floor. The student then solved multiplication problems using the large numbers on the floor, explaining the procedure verbally as it was completed. The student would often forget where the carried numbers would go, so physically moving the numbers helped his/her understanding.

Student 5. Student 5, like Student 2, began with only a knowledge of the times tables. Like student 2, the researcher began by testing Student 5's knowledge of the times tables using Braille flash cards, since this student also could not complete any problems on the pre-test. Also like Student 2, this student used the Brannan Cubarithm Slate to practice the problems and practiced only double-digit numbers multiplied by single-digit numbers using the standard American algorithm. This student also used the Brannan Cubarithm Slate to complete the problems on the post-test.

Student 6. As stated earlier, student 6 was the most advanced in mathematics. This student was able to complete simple division problems which required only a knowledge of the times tables. This student, like students 1 and 2, did not require much vision modification. This student used a combination of paper practice and large floor problems to practice division. The researcher wanted to make use of one of the Mr. Duey raps, but could not access them through the computer in the classroom due to security settings. During the course of the research, this student moved from dividing double-digit numbers by single digit numbers to dividing up to 5 digit numbers by single-digit numbers. A particular area of interest was dividends in which the first digit was smaller than the number in the divisor.

For more explanation of the manipulatives and activities used in this research, see appendix.

Results & Observations

Results were measured by comparing the percentage correct on the pre-test to the percentage correct on the post-test, and the time it took the students to complete each test. During the research, the researcher also recorded observational data regarding student attitudes toward mathematics before, during, and after receiving additional mathematics practice. These were compared to assess whether positive student attitudes toward math increased, decreased, or remained the same.

All students' attitudes and test scores improved following the research. As a group, the test scores of the students who were assigned to a combination of rote and multisensory practice improved more than those of the students who were assigned only rote practice. Two students did not know enough about mathematics to begin the pre-test, getting 0%. Both of these students improved, one to 10% and the other to 20% on the post-test. One student got only 7% of the questions on the pre-test correct; on the post-test, this student was able to answer 71% of the questions correctly. Other students made smaller gains, but all made gains; one student went from 30% correct on the pre-test to 40% correct on the post-test, another went from 35% to 80%, and the remaining student went from 33.3% to 80% correct from the pre- to post-tests, respectively. The table below summarizes the results from the pre- and post-tests.

	Pre-Test		**Post-Test**	
Student Number	Time to Complete	Percentage Correct	Time to Complete	Percentage Correct
1	13 min.	30%	70 min.	40%
2	12 min.	0%	24 min.	10%
3	12 min.	33.3%	48 min.	80%
4	24 min.	35%	27 min.	80%
5	12 min.	0%	35 min.	20%
6	34 min.	7%	12 min.	71%

Three of the students at the beginning of the research project said they enjoyed math and felt that it was easy for them. Two students said that they did not feel strongly about math either way and that it was not too easy or too hard. One student stated that he/she hated math, saying that it was boring and too hard. At the end of the research, the positive attitudes remained unchanged, the one student who did not have strong feelings about math at the start changed to enjoying math, and the student who expressed negative feelings toward math had a more positive attitude about math at the end of the research.

Student 1 seemed to enjoy all the activities he/she was asked to do during the course of the research; sometimes adding his/her own imagination to make the activity more meaningful or more challenging. For example, one day while practicing subtraction with the Digiblox, this student decided he/she would pretend to be a storeowner and had the researcher "buy" some of the stock. Another day, while using the virtual base-ten blocks, this student wanted the researcher to time how quickly he/she completed each problem. This student often made comments like "this is easy" or "I should always do math like this", referring to the use of manipulatives. When presented with print problems to be solved using manipulatives, however, Student 1 was less enthusiastic. He/she seemed to enjoy using the manipulatives still, but wanted to get through the written problems so that he/she could go back to doing activities using only manipulatives.

Student 2 also seemed to enjoy all the activities he/she was asked to do. One day, Student 2's teacher of students with visual impairments told the researcher that this student was very excited and asked whether "the math teacher" was coming that day, as he/she was looking forward to it. This student, too, made comments like "that was fast" after a session ended or, "this is easy!" when presented with a problem he/she was able to complete, and made many jokes during the course of the research. However, although the student seemed to be enjoying the mathematics practice, he/she did not seem to be grasping the steps of the algorithm as the research continued, having particular difficulty with where carried numbers should go.

Student 3 stated at the beginning of the research that he/she loved math and found it easy. This attitude pervaded the time the researcher spent with the student. When the time came to end the session for the day, the student often asked for "just one more" problem. One day, student 3 was in the classroom while the researcher was working with another student. Student 3 asked for some problems to do while he/she waited for the teacher of students with visual impairments to return, stating that he/she loved math and wanted to do it all day, every day.

Student 4 said at the beginning of the research that he/she enjoyed math and found it easy, however, some of his/her behavior seemed to disagree with this statement. When the student was doing the problems correctly, he/she appeared happy and seemed to enjoy the activities. When the student was making mistakes, however, he/she would make frustrated noises, sighing often and growling on occasion. One day, the student seemed to enjoy doing the math; on this day, the student made no mistakes. The student was also highly motivated by being allowed to use a marker to write when he/she practiced problems on paper. At the end of research, the student still maintained that he/she enjoyed math and found it easy, his/her attitude was unchanged.

Student 5 stated at the beginning of the research that he/she hated math, saying that it was boring and difficult. During the research, the student appeared to have neutral feelings toward the activities. The student completed the activities accurately and without complaint, but never gave any indication of positive feelings toward the activities, either. At the end of the research, however, this student stated to me that math was "kind of cool", it was easier for him/her, and he/she did not hate it anymore. This student was another who asked the teacher of students with visual impairments if "the math teacher" was coming that day as he/she was also looking forward to it.

Student 6 said at the beginning of the research that math was not too difficult, not too easy, and did not feel strongly positively or negatively toward math. During the research, this student seemed to enjoy the activities, and liked creating problems for the researcher to solve, too. One activity seemed to frustrate the student. The researcher laid out a problem that was incorrectly solved. The student was asked to figure out what was wrong by walking through the steps to reach the correct answer with the researcher. When this student was unable to figure out what was incorrect, he/she started wandering around the classroom trying to avoid the activity. The student also seemed very interested in what he/she was doing in his/her general education class, which at that point was learning Roman Numerals. The student wanted to solve problems using Roman Numerals, so the researcher tried to work those into the practice to increase this student's motivation. At the end of the research, this student's attitude toward math remained the same; not too difficult, not too simple, and had no strong negative or positive feelings toward math.

Not only did the students' test scores and attitudes improve, but the number of problems attempted on the post-test increased dramatically. As stated before, two students were unable to even begin the pre-test. On the post-test, nearly every student attempted 100% of the problems, compared to only one student that attempted every problem on the pre-test. This in itself, without any observational data, demonstrates the students' growing comfort with math concepts.

Student Number	Pre-Test % Attempted	Post-Test % Attempted	Difference
1	65%	85%	20%
2	0%	100%	100%
3	100%	100%	0%
4	75%	100%	25%
5	0%	100%	100%
6	71%	100%	29%

Part 2

Part 2 is a follow-up of the first part of this research, performed with students in a different school district almost a year following the completion of Part 1. This part, too, was based on a pre-test/post-test comparison and observational data.

Participants

The participants in the research in this case are five students, three in fourth grade, one in fifth grade, and one in sixth grade, all of whom have visual impairments of varying severity and all of whom are operating at an early fourth-grade level, two months to two years behind their sighted classmates in math, based on the Michigan Grade Level Content Expectations. All students are from the same low-income, urban school located in the Midwest region of the United States.

To protect the identity of the students participating in this research, each student was randomly assigned a number (1-6) using a calculator with a random number generator. All students were taught division using a rote rehearsal method, which was used in their general education classrooms with a small amount of supplemental multi-sensory rehearsal.

Student 1 has low vision and does not need extensive vision modifications. This student has difficulty performing simple multiplication, and struggles with addition and subtraction. However, this student was able to recognize enough of the relationship between multiplication and division to answer 33% of the questions on the pre-test correctly.

Student 2, a braille reader, requires alternative methods of accessing mathematics. This student had some understanding of the relationship between multiplication and division and was able to apply this knowledge to basic division facts.

Student 3 is a Braille reader, also requiring alternative methods of accessing mathematics. This student struggled with basic multiplication and division facts, and lacked automaticity with multiplication facts.

Student 4 is able to read print and does not need extensive vision modifications. This student was absent for the first few sessions of the research, and missed a lot at the beginning. This student was unable to begin the pretest, because he/she had no previous knowledge of division.

Student 5 is able to read print and does not need extensive vision modifications. This student, too, was unable to begin the pretest, also having no previous knowledge of division.

Method

Because all students were being taught the same level of mathematics in school, methods and lessons used were the same for all five students. Students first took a pre-test in their preferred learning medium (print, large print, Braille, read-aloud, etc.) to find a baseline skill level. The pre-test included skills they had not yet learned. The pre- and post-tests were timed for another level of comparison, but students were told to take as much time as they needed to complete the test. Because the researcher had already worked with the students daily for two months, the researcher was already aware of the skills the students had and still needed to obtain. The topic of study was based upon this knowledge.

This portion was different from Part 1 in that, the students in Part 1 had already learned the information in their classrooms and met with the researcher solely for rehearsal. The students in Part 2 got both their mathematical instruction and rehearsal from the researcher, rather than in their general education classes. The researcher met with students as a group almost daily for one month. Each instruction and rehearsal session lasted fifteen minutes to one hour. Another difference was that all students received a mixture of rote and multisensory rehearsal methods, rather than assigning different methods, due to the group setting for instruction. All students were also learning the same skill, rather than learning different skills individually.

One of the multisensory materials used with this group were unit cubes with cups, muffin tins, or white boards with circles to separate groups. This allowed students to start with a number of cubes, and divide them evenly between groups to discover how many cubes would go into each group. This helped students to grasp the underlying meaning of division, and was then connected to the division done on paper. Other materials used with this group were Braille and large print multiplication charts. These allowed students to connect multiplication to division where they were unable to do so before the study. The Braille readers both used Math Windows, a tool similar to the Brannan Cubarithm Slate, but magnetic and without assistance in lining up problems. This allowed students to manipulate numbers in a more accessible way. A final multisensory tool was a pair of large dice. These dice had high contrast and tactile dots so that students could roll the dice to create a division or multiplication problem to practice solving.

Results & Observations

As in part 1, results were measured by comparing the percentage correct on the pre-test to the percentage correct on the post-test, and the time it took the students to complete each test. During the research, the researcher also recorded observational data regarding student attitudes toward mathematics before, during, and after receiving multisensory and rote mathematical instruction and additional mathematics practice. These were compared to assess whether positive student attitudes toward math increased, decreased, or remained the same.

All but one student's test scores improved following the research. Two of the students at the beginning did not have enough knowledge of division to even begin the pre-test. Two students were able to answer less than half of the questions correctly, and only one student was able to correctly answer half of the questions. None of the students were able to correctly answer more than half of the pre-test questions. Following the research, two students were able to answer half of the questions correctly, and two students were able to answer more than half of the questions correctly. The final student looked at the test and stated that he/she did not know division. The researcher encouraged this student to try it, explaining that he/she had done division all month, sometimes with no help at all. Following this encouragement, the student attempted 16% of the problems, and then turned it in with a note at the bottom restating that he/she did not know how to complete the test.

In retrospect, part of the cause for the last student's confusion could have been the layout of the test. This student was absent during the introduction of long division, and so to the best of the researcher's knowledge, had never seen division problems organized in a vertical arrangement. The division test was set up in such a way as to support students who wanted to use their long division skills. The lack of a horizontal arrangement of division problems was a weakness of the pre- and post-tests.

	Pre-Test		**Post-Test**	
Student Number	Approximate Time to Complete	Percentage Correct	Time to Complete	Percentage Correct
1	5 min.	33%	15 min.	50%
2	5 min.	50%	3 min.	83%
3	7 min.	17%	12 min.	83%
4	2 min.	0%	5 min.	50%
5	1 min.	0%	2 min.	0%

Following the research, all students' attitudes toward mathematics seemed to improve or remain positive. One student seemed to feel more confident about his/her math skills than the other students from the start. Two students seemed to have no strong feelings either positively or negatively toward math. Two other students, however, seemed to find math difficult, confusing or boring. These two students seemed unwilling to attempt problems independently without constant support from the researcher. During the course of the research, the researcher saw some fluctuation in the attitudes of students toward math. Some days, certain students had a more positive attitude toward mathematics; the next day those same students would demonstrate a negative attitude toward mathematics. This seems to be a natural fluctuation based on mood and the level of difficulty of the task set before the students.

Student 1 seemed to have no strong feelings toward math at the beginning of the research. This student appeared happy when he/she understood the task set before him/her, and was willing to participate even when the task was something that he/she did not quite understand. This student's lack of automaticity in addition, subtraction, and multiplication made division more difficult for him/her to understand.

Of all the students at the beginning of the research, Student 2 seemed to feel most confident in his/her mathematical ability. Having gained some knowledge from listening in his/her general education class, this student understood the relationship between multiplication and division from the beginning and was able to apply this knowledge to basic division facts. This student was able to complete problems faster than his/her peers and was more independent in rehearsal activities.

Student 3 appeared to have a very negative attitude toward mathematics at the start of the research. This student got frustrated quickly and often interrupted instruction with comments that the task was hard or confusing. As the research continued, this student would repeat these sentiments, but his/her work suggested that this student understood more than he/she thought or was willing to admit. In fact, on the post-test, this student was the only one to attempt the most difficult problem and was one small mistake away from giving a correct answer. At one point during the research, the student got very excited about his/her discovery that division and multiplication were related, and was able to complete more problems independently following this realization.

Student 4 also seemed to have no strong feelings positively or negatively toward mathematics. Student 4 caught on to concepts of division quickly, which was very helpful to him/her because of many days of absence during the introduction to division. When working with manipulatives, this student seemed at his/her best. He/she seemed to grasp the concepts better with manipulatives than he/she did just working through the concepts on paper. The researcher observed that the transition from manipulative to paper was smooth, with a seemingly easy transition from hands-on manipulatives to paper work for his/her general education class.

Student 5 seemed to have a negative attitude toward mathematics at the start of the research. This student's behavior and comments at the beginning of the research project led the researcher to believe that this student was not comfortable enough with his/her mathematical skill level to attempt independent math work. The student would often look at a problem, see that it was division work, and immediately state that he/she did not know the answer or how to do the problem, that it was too hard, and was unable to specify with what he/she was having difficulty. About halfway into the research, this student seemed to gain some confidence in the use of manipulatives enough to correctly solve twenty problems completely independently, with no prompts or assistance. It was interesting to see the student's reaction to the post-test following this previous demonstration of confidence. This student was the one that stated that he/she did not know how to do division and attempted only one problem. The researcher believes that the negative reaction to the post-test is based partially on the faulty layout of the post-test and partly on the student's desire on the day of the post-test to complete reading work from earlier in the day.

Again, even with Student 6's difficulty with the post-test, the improvement in questions attempted on the pre- and post-tests is apparent. More students involved in Part 2 attempted a higher number of problems on the pre-test, but again, none of the students attempted to solve all of the problems on the pre-test. In this case, three out of five of the students attempted all of the problems on the post-test, one attempted half, and only one attempted less than half of the problems.

Student Number	Pre-Test %.Attempted	Post-Test % Attempted	Difference
1	33%	100%	67%
2	50%	100%	50%
3	33%	100%	67%
4	0%	50%	50%
5	0%	16%	16%

Application/Implications

This information is important for teachers of students with visual impairments, as well as for teachers in general education classrooms. For both, the knowledge that any extra practice in mathematics can improve not only mathematical performance, but also attitudes toward mathematics is a valuable tool. Teachers of students with visual impairments can communicate with teachers in general education classrooms about multisensory activities or other strategies that will be useful when working with students with visual impairments. Making general education teachers aware of available tools for students with visual impairments in math, such as the Brannan Cubarithm Slate, will be helpful for these teachers so that they are aware of ways for students with visual impairments to access that part of the curriculum.

The need for communication between special educators and general educators cannot be overemphasized. General education teachers must be in contact with the teachers of students with visual impairments so that the teachers of students with visual impairments are able to create appropriate materials for their students in a timely manner. Teachers of students with visual impairments must communicate with general education teachers so that these teachers are aware of the types of adaptive devices their students will be using and some of how these devices work so that general education teachers can assist students with visual impairments in their classes.

Suggestions for Future Research

In this research project, the researcher did not distinguish between students who had low vision and students who were totally blind, or even between print and Braille readers. Future research could compare strategies that work best for print readers or students with low vision, and strategies that work for Braille readers or students who are totally blind. Looking into the different areas where these students struggle with mathematics is another area in which research could be done.

The pre- and post-tests given in Part 2 of this research project could have been more accessible to students with varying levels of mathematical skill. The main weakness of these tests was the sole use of the vertical layout of division problems rather than a mixture of horizontal and vertical layouts. This contributed to confusion for at least one student, so it did not accurately measure what this student had learned, and may have had the same effect for other students without the researcher's knowledge.

In this research project, the sample size was very small due to the low incidence of visual impairment, and the amount of time needed with each student. Because there was only one researcher, one-on-one work with the students in Part 1 made it impossible to have a larger sample size. Future research performed by more than one researcher could use a larger sample size so that these results could be more conclusive than those found in this research project could.

Appendix

Activity/Manipulative Used	Purpose	Description of Activity/Manipulative
National Library of Virtual Manipulatives	Gain greater understanding of place value, practice subtraction	With this manipulative, students can solve either computer generated or student created problems using virtual base-ten blocks. It also demonstrates what steps in the standard American algorithm are completed as students move the base-ten blocks from column to column.
Digiblox	Gain greater understanding of place value, practice subtraction	These Digiblox are similar to base-ten blocks, but instead of trading ones for tens and tens for hundreds, the ones pieces fit inside the tens pieces, and the tens pieces fit inside the hundreds piece. The pieces do not snap closed unless there are exactly ten smaller pieces inside, which is helpful to students with visual impairments learning about place value.
Tactile Multiplication/Division Problems	Practice multiplication algorithm, integrate movement	Large multiplication and division problems were laid out on the floor and students would use the large numbers and operational symbols to solve these problems. Because students had to physically move numbers, for example carrying, it gave some students a more concrete reference for this skill.
Place Value Mat	Gain greater understanding of place value, practice subtraction	The place value mat was a simple sheet of paper with a line down the middle and "Tens (10s)" written in the left column and "Ones (1s)" written in the right. The

		student would then build numbers on the mat using the Digiblox and putting the tens and ones pieces in the correct column. Later, the student used this for subtraction, as well.
Mr. Duey Rap	Integrate auditory learning, set up division problem, learn division algorithm	The Mr. Duey website has educational raps that the creator has found to help increase student academic performance. The particular rap the researcher wanted to use in this research walks students through the procedure to set up and solve a long division problem.
Brannan Cubarithm Slate	Practice multiplication with Braille	The Brannan Cubarithm slate is a board with many spaces into which cubes can be placed. These cubes have Braille numbers on each surface so students can set up and solve a problem far more easily than they would be able to on a braillewriter. It helps ensure that the numbers are lined up properly, as well.
Braille/Large Print Flash Cards	Test student knowledge of times tables	These were used much the same way as flash cards for sighted students, except that instead of holding the cards up in front of the student, the cards are placed on the desk in front of the student so that he or she can read the Braille and give his or her answer verbally.
Unit Cubes and Cups or Muffin Tins	Gain greater understanding of basics of division	Students were given a division problem and the starting number of unit cubes. The students had to divide the cubes into the correct number of groups using cups, a muffin tin, or just groups on the table.

		This was related to the division problem verbally and in print, so the student first spoke their answer, and then recorded the answer on a worksheet.
Braille and Large Print Multiplication Charts	Strengthen connection between multiplication and division	Students used multiplication charts in their learning medium to practice basic division problems and to solidify the connection between multiplication and division as related operations.
High Contrast, Tactile Dice	Give randomized problems for students to solve, integrate tactile learning style	Students rolled the dice to determine the divisor, and then rolled one die to determine the dividend. They then practiced solving these division problems using either the standard algorithm, unit cubes, or multiplication charts.

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