The Effect of a Short-Term Intervention with Middle School Students: Will the Use of Manipulatives Enhance Multiplication Fact Fluency?

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Abstract

Many students struggle with attaining a grasp on the many mathematical concepts they are expected to learn. Although research has found that many different teaching strategies produce different results, one approach that has been found to be promising is the use of manipulatives. This study focused on the use of unifix cubes, which are common manipulative materials, as a strategy for teaching multiplication to middle school students. The study sought to determine if having physical, tactile objects to help represent the multiplication problems could help middle school students gain a better understanding of multiplying by 8's (the multiplication table which was determined to be of the greatest difficulty). While an overwhelming majority of students reacted positively to the use of the manipulatives, no significant difference was found in achievement of multiplication fact fluency after a single intervention. The methodology and approach can be scaled for a more prolonged study with a larger sample, which might yield different results.

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Middle grade students (6th, 7th, and 8th) at Almeria Middle School in Fontana, California have been placed in a math intervention class due to their need for extra support in mathematics. The level of need for these students is indicated by their “tier,” such that “tier 1” is for students who need a small amount of extra help, usually provided by the core subject teacher, “tier 2” is for students who are 1 to 2 years below grade level, where intervention services are provided by an instructional support teacher in an intervention class, and “tier 3” is for students who are performing significantly below grade level and require intensive instructional support. The students in this study are a part of a “tier 2” intervention class. An area with which many of these students struggle, as determined by various assessments and teacher observations, is memorizing multiplication facts. In light of the promising benefits of using manipulatives for mathematics instruction, this study uses an experimental design to investigate the effect on achievement for “tier 2” intervention middle school students when multiplication tables are taught using unifix cubes (common manipulative materials) as compared to when the lesson is taught without manipulative materials. As reported by the teacher, the tables of numbers that most often provide the greatest difficulty for the students are those of 7’s, 8’s, and 9’s, and this study focuses on those multiplication fact families. In addition to investigating achievement, subjects in the treatment group using the unifix cubes will be asked to answer a narrative question to determine their attitude toward the use of manipulatives as an instructional strategy for teaching multiplication.

Literature Review

The concept of multiplication has been explored in many contexts, and some of those contexts seem to support the use of manipulative materials in teaching multiplication. Research conducted by Park and Nunes (2001) attempted to gather evidence on which concept of multiplication lent itself best to teaching: repeated addition or correspondence schema (i.e., how much of *this* corresponds to how much of *that*). The authors concluded that “practice in one-to-many correspondence as a means of solving multiplicative reasoning problems is significantly more effective than practice in repeated addition” (p. 771). The authors also indicate that even after just a short intervention, lasting an hour, there were significant differences among the groups, although they caution it was a preliminary study and that the sample was small (Park & Nunes, 2001, p. 772). This favored method of instruction, correspondence reasoning, has its roots in concrete, everyday problems. The use of manipulative materials, it follows, might provide a way to facilitate the correspondence schema instruction methodology, as these materials can be used to quickly form groups that demonstrate correspondence relationships.

Much research has been done to try to reconcile the conflicting evidence surrounding the use of manipulatives (Uttal, Scudder & DeLoache, 1997). Moyer (2001), later Uribe-Flórez (2011), and Pham (2015) set out to understand how different teachers use manipulatives in their classrooms and what factors contribute to their effectiveness in teaching mathematics. Moyer (2001) found that despite a 2-week summer instructional program on the use of manipulatives to teach mathematics, the belief systems of the teachers, not their knowledge of how to use them, affected the frequency and efficacy of their use of manipulatives. Many teachers relegated the use of manipulatives to being part of a reward system for good behavior or for free time, but not as a necessary part of the instruction of mathematical concepts. However, Moyer found that a teacher’s effectiveness in their use of manipulatives was mostly related to three things: their concept of mathematics, their concept of manipulatives, and their belief regarding the purpose of manipulatives in teaching mathematics (2001).

The findings of Uribe-Flórez (2011) indicate that there are considerable differences in how teachers use manipulatives. The researcher concluded that teachers' beliefs and grade level are significant forecasters of how frequently teachers utilize manipulatives in teaching mathematics (Uribe-Flórez, 2011). Pham (2015) wished to understand the effectiveness of utilizing manipulatives in teaching math and how teachers utilize manipulatives to assist students to understand complex concepts in mathematics. The findings showed that teachers who used manipulatives in their math instruction had a considerable impact on the way the students comprehended the mathematics subject. Pham (2015) concluded that the use of manipulatives improved student interest, and helped them to be passionate and enjoy learning.

These results were congruent with earlier research on the use of manipulatives, supporting an increase in learner achievement as a result of enhanced clarity in understanding mathematical concepts and integral basic mathematical models (Pham, 2015). But as mentioned before, there is conflicting research on whether the use of manipulatives actually increases student achievement. Belenky & Nokes (2009) conducted an experiment using metacognitive statements in combination with the use of manipulatives. Students who were given concrete manipulatives with metacognitive prompts did show better transfer of a procedural skill than students given abstract manipulatives or those given concrete manipulatives with problem-focused prompts. However, the researchers concluded that using manipulatives did not produce any differences in overall problem accuracy for the participants. They also did not see any difference in participants' ability to correctly choose which formula applied in a given problem.

With the advent of increased access to computers in the classroom, researchers have been interested in examining the effectiveness of using virtual manipulatives versus physical manipulatives. However, teacher beliefs are as influential in their use of multimedia (Reshan, 2012), as they are in their use of technology tools (Suh & Moyer, 2005). Suh and Moyer investigated the learning characteristics afforded by the use of virtual manipulatives, including discovery learning, the combination of visual and symbolic images in a linked format, and the prevention of common error patterns. In their study, students identified as low-achievement seemed to benefit most out of the three groups of students (high, average, and low) from working with the virtual concept tutorials. However, their study used observations of students, and did not examine the effect on achievement that might be produced by using physical manipulatives or virtual manipulatives for instruction. Moyer-Packenham et. al. (2013) conducted an experiment with virtual fraction manipulatives to investigate the effect on achievement. Their results revealed no significant overall differences in achievement between the groups using virtual manipulatives and the groups using physical manipulatives.

Leaving virtual manipulatives aside, the current study proposes to examine the effect that physical manipulatives might have on achievement when compared to a lesson plan that is nearly identical, removing only the tactile component (one which uses graph paper instead of physical cubes). In this way, the researchers hope to determine whether a short-term intervention with manipulatives can enhance multiplication fact fluency for the students.

Assumptions

The two groups (control and treatment) in the study are assumed to consist of students who are of the same age, socio-economic background, and academic achievement levels. The pre- and post-assessments will be administered and scored utilizing the website

Multiplication.com and the assumption is that this website is a valid instrument for assessing students' multiplication fluency.

Research Questions and Concerns

Will learning outcomes be greater when students are taught multiplication concepts using unifix cubes? The research group hypothesized that students would increase their multiplication accuracy for a specific multiplication table (7's, 8's, or 9's) after exposure to a lesson using physical manipulatives. The research group also hypothesized those students who score 100% would be able to decrease their time to complete the instruments. The justification for this hypothesis was that physical objects used to demonstrate the multiplication process might aid the students in obtaining a better understanding of multiplying numbers. Concerns about limited time and the number of students in the sample may possibly restrict the study.

Definitions of Terms

The following definitions of terms apply to the current study:

Unifix cubes. These manipulative materials are interlocking cubes, with only 1 outer port and 5 inner ports used to connect each cube, and are intended to help students from ages 4 and beyond to learn early math concepts. They are colorful, made of plastic material, and are intended to give students a fun, hands-on experience.

Manipulatives. These are any objects that students use in order to physically model a mathematical concept. Objects include, but are not limited to blocks, tiles, cubes, counting bars, fraction pieces, etc.

Control group. This group (also called the comparison group) consists of the students who did not receive the treatment intervention in the experiment. This group is being compared to the treatment group.

Treatment group. This group (also called the intervention group) consists of the students who received the treatment intervention in the experiment. This group is being compared to the control group.

Significance of the Proposed Study

Students in the middle school classroom where the study will be conducted have shown deficiency in their knowledge of multiplication tables, especially with the 7’s, 8’s, and 9's. The study will determine which multiplication table is most difficult for the students, and will attempt to measure the increase in achievement for this table by testing their fact fluency, comparing scores from the pretest to the posttest. The teacher of the students who are participating in the study is interested to see if her students can show improvement in memorizing multiplication facts utilizing unifix cubes as a multiplicative strategy. The attitudes of the students using the manipulatives will also be recorded, as these can be a significant indicator in determining whether future multiplication studies for middle school students should include manipulatives.

Design and Methodology

Subjects

Participants in the study included an Instructional Support Teacher who teaches math intervention classes and her students from Almeria Middle School, a public 6th through 8th grade middle school in Fontana, California. Students in the math intervention class, ranging from grade 6 through grade 8, and ranging in ages 11 through 13 make up the sample. A total of 62 students participated in the experimental study and 1 teacher. The student-participants are mostly Hispanic, primarily English-Language Learners, come from a low-socio-economic status (as determined by the number of qualified free lunches), and have already been placed in the math intervention class based on the district-determined criteria which include performance on state and district-wide assessments. Students from the math intervention class were purposefully selected due to the teacher noticing that many struggled with multiplication fact fluency. Student names were removed and replaced with the class period number, seat location, and gender. Lastly, students were assigned to either the treatment group or control group through random assignment.

Data Collection

On the pretest day, two research group members went to Almeria Middle School to assist with administering this assessment. First, the teacher informed students that they were going to complete three pretests to assess their fact fluency on multiplying with 7's, 8's, and then 9's. The teacher explained to the students how to open the link to do the pretests on Multiplication.com and also how to print their results. Second, the group members walked around the classroom while the students were completing their pretests to make sure students had no technology issues. Students were seen using their fingers and some tried to calculate by using scratch paper and a pen while they were completing their pretests. After students completed the three pretests, they were given a small recording sheet where they wrote down their Time (minutes: seconds) and Score (percentage correct) for each pretest. These scores were analyzed by other members of the research group after the raw data was entered into an Excel spreadsheet.

On the posttest day, two different research group members went to Almeria Middle School to assist with administering this assessment. All members of the treatment and control groups took the posttest without interruption. Because analysis of the pretest results indicated that the 8's multiplication table was the one presenting the greatest difficulty for the students, the students completed a posttest on 7's and 8's to better replicate the conditions on the pretest day for the 8's multiplication test.

Treatment Procedures

The teacher planned the lesson based on the pattern noticed when students were asked to solve mathematics problems which involved multiplying factors of 7's, 8's, and 9's. After the pretest was given, it was determined that these students mostly struggled with the 8's fact family. The teacher designed two lessons (see Appendix A): one lesson for the treatment group using manipulatives to break down the factors of 8, and one lesson for the control group using graph paper and area models to draw the factors of 8 as lengths of rectangles.

The class period was a total of 57 minutes, with the first 5 minutes of class being routine school business, and then 20 minutes dedicated to the treatment group working with the teacher while the control group students worked independently on the computers (a part of the normal classroom routine), and then a rotation so that the control group worked with the teacher for 20 minutes while the treatment group students worked independently on the computers. The last 5 minutes of class was dedicated to cleaning up and attending to regular school business.

During the lessons, students were instructed through an introduction, direct-teaching, a first guided practice, a second guided practice, independent practice, and then a closure. However, the closure was more of a reflection and was not recorded from students until the day after the intervention lessons were taught and students were given the posttest.

Instruction for the treatment group included having students connect the unifix cubes to show groupings for the 8's multiplication table, and then break apart the unifix cube groups to show factors. Instruction for the control group followed the exact same format, but the students used graph paper in lieu of manipulative materials. Also important during the lesson, students were able to work with partners and/or consult with partners for assistance. Students seemed compliant in following the teacher's guidance and were engaged in answering the questions the teacher posed related to the 8's fact family. One unforeseen note, the teacher ran out of time with the control group and did not have them work on independent practice problems as planned for in the lesson plans (see Appendix A).

The day of the posttest, students from the treatment group were asked to write a response for their opinion on whether or not they liked using the unifix cubes to multiply. Students were specifically asked, "Did you like using the unifix cubes to multiply? Why or why not?" Students wrote their responses on the top page of their posttests (see Appendix B).

Presentation of Findings

For students who scored 100% on both the pretest and the posttest, the time it took for them to complete each test was compared, and for those students who did not score 100% on both pretest and posttest, the scores were compared. The treatment group and the control group were statistically equivalent based on the scores of the pretest. The mean time for the pretest for the 11 members of the treatment group who scored 100% on both the pretest and the posttest was 58.5 seconds, the median time was 49 seconds, and there was no mode. The range was from 36 seconds to 105 seconds, and the standard deviation was 20.7 seconds. In the control group there were also 11 members who scored 100% on both the pretest and the posttest. The mean time for those members of the control group was 57.5 seconds, the median time was 53 seconds, and the mode was 67 seconds. The range was from 40 seconds to 85 seconds and the standard deviation was 12.8 seconds.

The mean time for the posttest for the 11 members of the treatment group was 47.7 seconds, the median time was 45 seconds, and the mode was 50 seconds. The range was from 30 seconds to 78 seconds, and the standard deviation was 13.6 seconds. For the control group, the 11 members had a mean time of 48.5 seconds, the median time was 47 seconds, and the mode was 45 seconds. The range was from 36 seconds to 65 seconds and the standard deviation was 8.4 seconds. These findings are presented in Figure 1, with error bars representing the standard deviation.

Figure 1: The change in time from pretest to posttest for the members of the treatment group and the control group who scored 100% on both the pretest and the posttest.

The mean score for the pretest for the 14 members of the treatment group who scored less than 100% on either the pretest or the posttest was 82.9%, the median score was 87.5%, and the mode was 70%. The range was from 45% to 100%, and the standard deviation was 15.5%. For the control group, there were 19 members who scored less than 100% on either the pretest or the posttest. The mean score for those members of the control group was 85.1%, the median score was 90%, and the mode was 95%. The range was from 40% to 100% and the standard deviation was 14.7%.

The mean score for the posttest for these 14 members of the treatment group was 90%, the median score was 92.5%, and the mode was 90%. The range was from 45% to 100%, and the standard deviation was 13.7%. For the control group, the 19 members had a mean score of 92.9%, the median score was 95%, and the mode was 100%. The range was from 70% to 100% and the standard deviation was 8.9%. These findings are presented in Figure 2, with error bars representing the standard deviation.

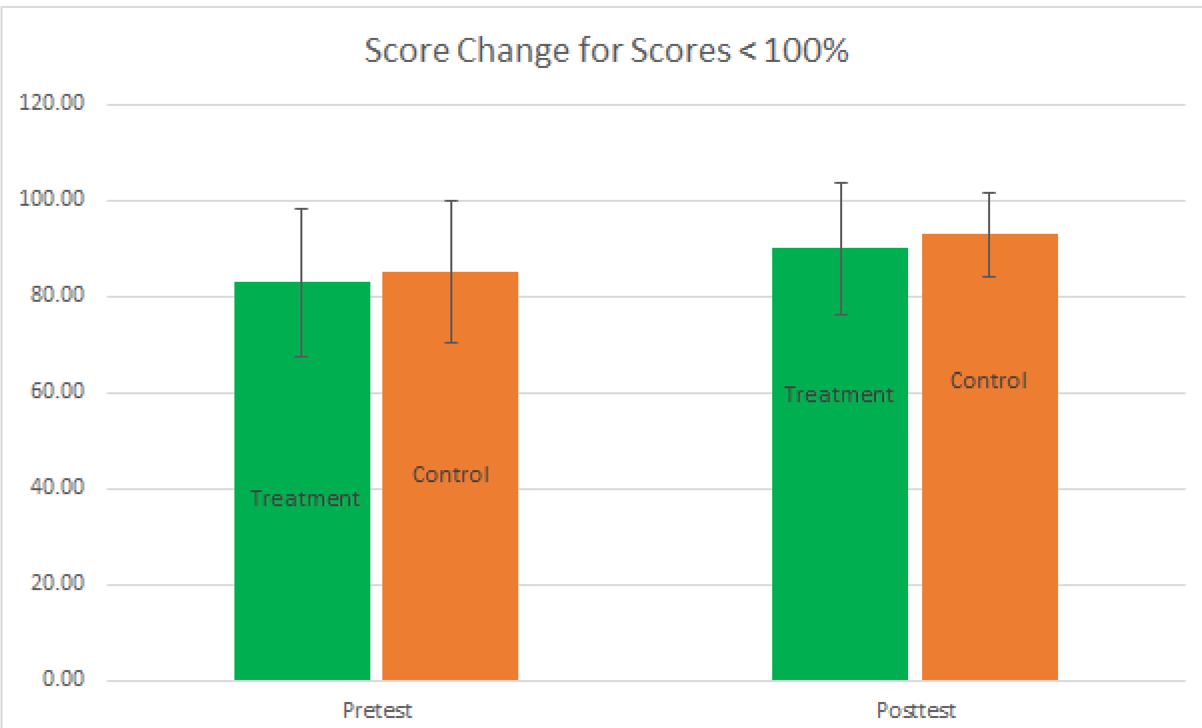

Figure 2: The change in scores from pretest to posttest for the members of the treatment group and the control group who scored less than 100% on either the pretest or the posttest.

After the treatment, the achievement scores and times of the treatment group were statistically the same as those for the control group. A t-test was performed using an alpha of

0.05, and no significant difference was found between the treatment group times and the control group times. A second t-test was performed using an alpha of 0.05 for the scores, and no significant difference was found between the treatment group posttest scores and the control group posttest scores.

In addition to the quantitative data, the research group members analyzed the answers to the narrative question that was given to the treatment group. Of the 25 students in the treatment group that were present for the pretest, treatment, and posttest, the responses were overwhelmingly positive. Of the 11 students who achieved 100% on both the pretest and posttest, only three indicated that they did not like using the manipulatives. The other eight students indicated that the unifix cubes were either “helpful” or made multiplication “easier.” All of the 14 students who scored less than 100% indicated that they liked the manipulatives, referring to the unifix cubes as “helpful” or that they made multiplication “easier,” and 4 students indicated that they even made multiplying “fun.”

Both intervention groups, control and treatment, increased their scores and decreased their times from pretest to posttest. Overall, the lesson plan was effective, but the use of the manipulatives did not significantly alter student achievement. Even though unifix cubes are more commonly used in the lower grades, students overwhelmingly indicated they liked using them. However, in many cases where students said the unifix cubes helped, those students did not score any higher on the fact fluency posttest.

Limitations of the Design

Time constraints limited the length of the intervention to only one day. Interruptions to the classroom (phone calls, students called out of class, etc.) also limited the implementation of the lesson plans. The pre- and posttests only had 20 problems each, which limits the data analysis for checking the frequency of students' errors. The initial constrained sample size was made even smaller due to students not being present on all days of the research study. New students were added to the sample due to schedule and enrollment changes to the classes, but these students were not a part of the pretest and/or intervention. The sample size is significant for the current study, but in the broader spectrum, the sample size is small and made it difficult to establish a significant relationship between the treatment intervention and the improvement in achievement.

Conclusions & Recommendations for Future Research

Rarely can a single intervention result in a significant improvement in achievement. Yet, the research shows that longer, more in-depth interventions which target students' learning deficiencies can only be as successful as the teacher who is willing to try new teaching strategies. Ultimately, students need to be given every opportunity to create a personal strategy that works for them, and if teachers are invested in using manipulatives, then we can conclude that using unifix cubes as an instructional strategy for multiplication is no worse than using graph paper. If the students enjoy using manipulative materials and they are more engaged in the learning exercise, then there may exist benefits to their use that this study was unable to verify.

Those looking to further study the use of manipulatives in teaching multiplication might yield more conclusive results by increasing the sample size and administering multiple interventions over a longer period of time. Many types of manipulatives exist, such as fractional pattern blocks, base ten blocks, and Cuisenaire rods, etc. The use of other manipulative materials might yield a greater measure of enhanced achievement.

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Appendix A

The lesson plans and attendance for both the treatment and the control group are provided below.

	Warm-Up	Rotations: Software &	Introduction	Direct Teaching	Guided Practice 1	Guided Practice 2	Independent Practice	Closure
T 11/1 Unifix Cubes & Graph Paper	Display the groups, Group B (control group) on the computers first, Group A (treatment group) work with the teacher first.		Teacher will introduce the Unifix Cubes and explain what they can be used for.	Teacher will demonstrate how to use the Unifix Cubes to multiply 8 x 3.	Teacher will guide students how to use the Unifix Cubes to multiply 8 x 4.	Teacher will guide students to work with their partner to use the Unifix Cubes to multiply 8 x 6.	Students will work with their partners, but build their own Unifix Cubes to multiply 8 x 7 and then 8 x 8.	Exit Ticket: Did you like multiplying with the Unifix Cubes? Why or why not?
			Teacher will introduce the graph paper for drawing array models.	Teacher will demonstrate how to draw arrays to multiply 8 x 3.	Teacher will guide students how to draw their own array to multiply 8 x 4.	Teacher will guide students to work with a partner and compare the array to multiply 8 x 6.	Students will work with their partners, but draw their own arrays to multiply 8 x 7 and then 8 x 8.	Exit Ticket: Show of Thumbs - will you work on a strategy for memorizing the 8's Fact Family of multiplication?

Didn't get to Independent Practice with Control Group B.

	Group A (Treatment)	Total	Group B (Control)	Total
Period 1	2, 6, 10, 13, 14, 16, 19, 22, 24	9	1, 5, 9, 12, 15, 17, 18, 20, 21, 25 Red indicates the student was absent for the treatment.	10
Period 2	5, 7, 9, 13, 14, 16, 17, 18, 23, 24, 1 Red indicates the student was absent for the treatment. Magenta indicates the student was tardy +30 minutes and was not present during the treatment. Green indicates a new student added to the class as of 10/31/2016.	~~10~~ 11	2, 6, 8, 10, 19, 20, 21, 22 All students present in this group.	8
Period 3	1, 2, 5, 6, 10, 13, 15, 16, 19, 20, 21, 4 Green indicates a new student added to the class as of 11/1/2016.	~~11~~ 12	7, 8, 9, 11, 12, 14, 17, 18, 22, 23, 24, 25 All students present in this group.	12
	Total Overall:	32	Total Overall:	30
	Total Present During Treatment:	28	Total Present During the Lesson:	29

Appendix B

The narrative responses for a selection of the treatment group participants are provided here. The original spelling of the comments has been maintained. These responses are answers to the question, "Did you like using the unifix cubes to multiply? Why or why not?"

P3S13: "No, because I have 7 and 8's by heart. And it wasn't necesari."

P3S16: "I like to because it help with multiplication."

P3S15: "I did like using the unifix cubes to multiply, because it kinda helped me understand multiplication in an easier way and it ws really fun getting to do math in a differant and fun way."

P3S10: "Yes, because it made it a lot easier to multiply but it takes a while to put them all back" together.

P3S1: "Yes, I liked using the unifix cubes they make it easier for me to multiply problems."

P3S2: "No, because i like multiplying regular."

P1S16: "i liked using the unifix cubes because it was easier to multiply and it was more fun."

P1S13: "I like using the unifix cubes to multiply. Because it easier and kinda fun. They help me count easier it just makes things easier."

P1S10: "I kind I like it, and do not like it because one reason is when you can find a group to give

you answer is kind of hard to find another one. I like it because it is easier multiply by making groups and get your answer."

P1S6: "I used the unifix because i remember that it is easy to find other multiplication problems that have the same product."

P1S19: “I did like using the cubes because it helps me multiply certain things a little bit faster than usual and i think it’s fun to use them.”

P1S14: “Yes, I do because it helps me in the groups and I could just count them and theres the answer.”

P1S24: “Yes, I liked using the unifix cubes to multiply. Becase it is an eiser way to multiply numbers.”

P2S9-“I liked using unifix cubes because it helped me understand the many ways you can multiply to get the product with different factors.”

P2S23-“I liked using the unifix cubes to multiply. I found that it was eaisier to multiply when you split the number.”

P2S7-“Yes I liked using the unifix cubes because I can break down the multiplication problems wich makes it easier.”

P2S14-“I liked the unifix cubes because I know how to multiply all of them but some take me help me a lot.”

P2S24-“Yes, because it’s another way to multiply.”