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The Effects of Mnemonics to Increase Accuracy of Multiplication Facts in Upper-Elementary School Students with Mild to Moderate Disabilities

Logan James Eubanks
Utah Sate University

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Master's Project

The Common Core adopted by Utah in 2010 provides standards of core curriculum concepts for grades k-12. In mathematics, the Common Core states that students in grade three are to develop an understanding of multiplication and division and strategies for multiplication and division with numerals under 100. One standard set forth by the National Council of Teachers for grade four focused on developing quick recall of multiplication facts and related division facts and fluency with whole number multiplication. Students are to "develop fluency with basic number combinations for multiplication" and "develop fluency in multiplying whole numbers" (National Council of Teachers of Mathematics, p. 148). The importance of fluency in mathematics becomes evident when students lack this vital skill. "Without the ability to retrieve facts directly or automatically, students are likely to experience a high cognitive load as they perform a range of more complex tasks" (Woodward, 2006). The ability to immediately recall facts is more efficient than using other strategies because it allows students to respond with less effort and more speed. Increasing fluency for students with deficits in math is likely to improve their success in a mainstream setting.

Woodward notes that academically low-achieving students as well as those with learning disabilities (LD) have considerable difficulty developing automaticity in the four basic operations (Woodward, 2006). From my own experience, when discussing the performance of students being referred for special education, teachers often express frustration with these students' lack of response to fact fluency interventions. These students are frequently taught the basic facts using the same timed practice or repetition procedures that are used with students who do not struggle in math and who do not have

learning disabilities (Greene, 1992). This traditional rote method, while it teaches the basic facts, encourages students with learning disabilities to believe that mathematics is more memorizing than conceptual or logical thinking. This has serious disadvantages for students who struggle in mathematics and who are already acutely aware that they have difficulty recalling information (Isaacs, 1999). This way of thinking implies that math fact retrieval is not in one's own control, but rather depends solely on whether or not one is simply good at memorizing things; a kind of "you either have it or you don't" mindset, enabling a sense of helplessness. An issue that requires addressing is whether practicing the "drill and kill" method (e.g. timed drill practice or copy, cover, check) is appropriate for these struggling students to learn their facts. "Typical" students seamlessly move from procedural knowledge (ie. counting or repeated addition) to declarative knowledge (direct retrieval or just knowing) with their multiplication facts. Students with learning disabilities often struggle to reach the declarative knowledge level due to difficulties in developing ways to organize and remember the math facts. One tool that can help students with poor memory recall is mnemonic strategies. Scruggs and Mastropieri (1990) state that "mnemonic strategies have produced some of the largest, most consistently positive outcomes in special education intervention research" (p.271).

Broadly defined, a mnemonic is a "device, procedure, or operation used to improve memory". While that is correct, Scruggs' and Mastropieri's more detailed explanation is that a mnemonic is a "specific reconstruction of target content intended to tie new information more closely to the learner's existing knowledge base and, therefore, facilitate retrieval" (p.271-272). The use of mnemonics has been around for thousands of years starting with the ancient Greeks and mnemonic strategies have been applied in a

breadth of curricular content areas such as: music, vocabulary, language, social studies, mathematics and the sciences (Scruggs et. al, 1990).

Gary Greene (1999) conducted research with 23 elementary and middle school aged students with LD receiving math instruction in resource classrooms. The study identified 14 difficult to memorize multiplication facts and compared mnemonic instruction to traditional instruction using flashcards in an effort to increase the number of multiplication facts orally recalled. A within-subject counterbalanced design was used with students serving as their own control and receiving both mnemonic and traditional interventions (Greene, 1999). The results indicated that, while both groups increased the number of multiplication problems recalled, a larger increase was observed when mnemonic instruction occurred first (M=4.65, SD= 2.05) than when mnemonic instruction followed traditional instruction (M=3.53, SD= 2.49). Greene (1999) went on to report that results of this study imply that special education teachers should consider the use of mnemonics as a viable means for remediation of math fact deficits (Greene, 1999).

In the article, "Teaching Multiplication Facts to Students with Learning Disabilities", researchers Wood, Frank and Wacker (1998) examined the effects of an instructional package on the accuracy and performance in solving multiplication facts by three fifth grade students with LD. The participants were taught 100 multiplication facts using a modified instructional sequence where facts were grouped into six categories: zeros, ones, doubles (twos), fives, nines, and the remaining 15 facts with a mnemonic strategy referred as the peg-word method. Pegwords are rhyming proxies for numbers (one is bun, two is shoe, three is tree, etc.) and are used to remember numbered or

ordered information (Scruggs et al. 2000). The participants were taught to identify the grouping and use the specific instructional strategy to correctly answer the multiplication fact. All three participants responded positively to the intervention, often maintaining 100% after treatment for each particular grouping with the exception of the 15 pegwords facts, which resulted in a mean of 88% after treatment.

Wood et al. (1998) continue by stating the "underlying mechanisms for why instructional strategies such as mnemonics are effective need to be evaluated". They conclude that the results of their study suggest that matching instructional strategies to students needs can be a highly effective approach to intervention and warrants further evaluation" (Wood et al. 1998). Scruggs and Mastropieri (2000) state: "that the use of mnemonic or memory-enhancing strategies have been highly successful in improving the memory of specific content in populations of students who often experience academic failure". Furthermore, they advise teachers to consider the use of mnemonics as an effective tool in the area of memory with students with special needs.

Purpose

The intent of this project is to replicate a specific instructional method used in Wood et al.'s study focusing on the use of the pegword mnemonic strategy paired with stories and illustrations for 15 targeted multiplication facts remaining after mastering math facts in the zeros, ones, twos, fives, or nines groups. Three questions will be asked during this project on the effects of mnemonic instruction using pegword strategies on the percentage of multiplication facts answered correctly by third, fourth, and fifth grade students with learning disabilities? 1) Does pegword instruction paired with stories and illustrations result in immediate improvement for the specific multiplication facts taught?

2) Are students' performances on previously taught multiplication facts maintained as new multiplication facts are introduced? 3) Do students maintain accuracy on 2 and 4 week follow-up tests?

METHODS

Participants and Setting

Six students in grades four through five receiving special education services in mathematics participated in this project. All students received 45 additional minutes of daily mathematics instruction in the resource classroom by the special education teacher. Students in this project were selected based on their difficulty memorizing multiplication facts as evident in their insufficient progress on multiplication fact fluency goals in their Individualized Education Plan (IEP). Table 1 shows students' demographic information including: grade, classification, IQ score, a language/verbal standard score and a math achievement standard score. The language score was included since a language component was used in this intervention.

Table 1

Student	Grade	Classification	Test	IQ	Verbal/ Language	Test	Math
Tyler	4	SLD Math	WISC-IV	94	87	K-TEA-II	85
Trevor	5	SLD Math	WISC-IV	93	91	WIAT-III	81
Holly	5	SLD Math	WISC-IV	106	98	WIAT-III	80
Allen	5	Autism	WISC-IV	88	83	WJ-III	83
Sam	5	SLD Math	WISC-IV	99	96	WIAT-III	87
Peter	5	Orthopedic Impairment	WISC-IV	72	83	WIAT-III	82

Prerequisite and Targeted Skills

Prerequisite Skills

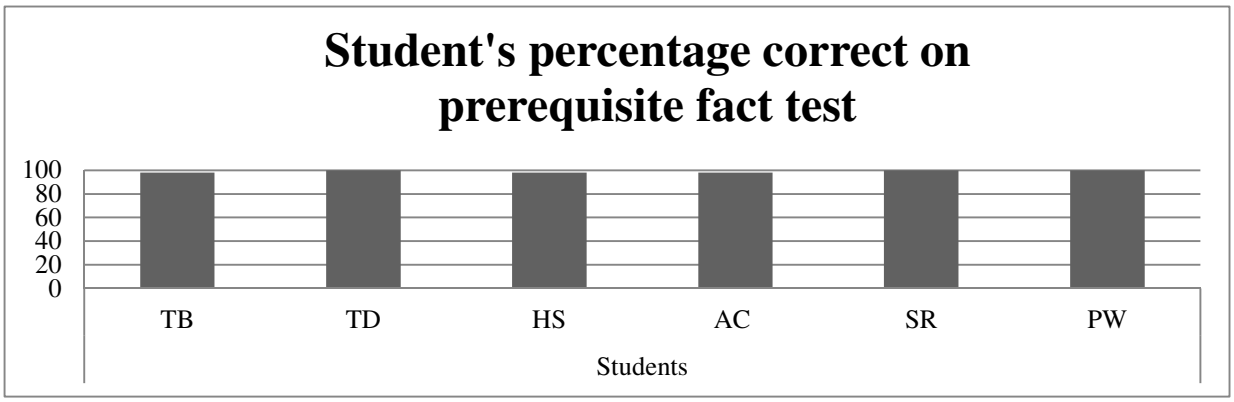
Prior to beginning this project, students were taught to mastery a collection of prerequisite multiplication facts. These prerequisite facts, as seen in Table 2, were categorized into five groups.

Table 2
Prerequisite Math Fact Skills

Multiplication Facts containing Factors:	Example		
Zeros	3 x 0 =	0 x 8 =	5 x 0 =
Ones	1 x 7 =	4 x 1 =	1 x 8 =
Twos	2 x 4 =	9 x 2 =	3 x 2 =
Fives	5 x 3 =	8 x 5 =	5 x 5 =
Nines	9 x 7 =	4 x 9 =	9 x 3 =

The teaching procedures for these groups may be found in Appendix A. Mastery for the prerequisite skills was determined when students successfully answered 80% or better on the paper and pencil prerequisites test containing 54 facts from the five groups. Student's scores on the prerequisite test are presented in Figure 1, (See the prerequisites test in Appendix B.)

Figure 1



Rationale for Selecting the 15 Memory Group Facts for Mnemonic Intervention

Multiplication with factors zero through nine creates 100 multiplication facts that students must learn. Teaching students the commutative property of multiplication cuts the facts to be learned down to 50 facts. The math facts targeted for this intervention were differentiated from the prerequisite math facts, because they are consistently more difficult for students to learn than the prerequisite facts. (See below for explanation of rules for the prerequisite facts.)

- Zeros: Easy to teach because the simple rule is that the product is always zero (i.e. 4 x 0 = 0).
- Ones: Easy to teach because the product is always the factor other than 1 (i.e. 1 x 7 = 7).
- Twos: Easy to teach because the product will be double the other factor (i.e. 6 x 2 = 12: six plus six is 12).
- Fives: Easy to teach because skip counting by fives is generally a mastered skill. Use "touch points" for other factor while skip counting by fives (i.e. 4 x 5 = 20, touch the four 4 times while counting by fives: 5, 10, 15, and 20. 20 is the product).
- Nines: Relatively easy to teach because of the simple rule; subtract one from the factor that is not a nine then link this digit with another digit whose sum is 9. (i.e. 9 x 7 = 63, seven minus one equals six, six goes in the "tens place" and three is linked with six for an answer of 63).

What remains after 0's, 1's, 2's, 5's, and 9's are learned are 15 multiplication facts for which there are no simple rules. These facts just need to be memorized. These 15 multiplication facts have been targeted for the intervention using mnemonics.

Target memory group facts

The intervention focused on the following 15 targeted multiplication math facts (Table 3). These facts were assembled into three groups with five facts each. Memory group 1 (MG 1) contained facts with a 3 as a common factor. Memory group 2 (MG 2) consisted of facts containing factors of 4 along with the 6 x 6. Memory group 3 (MG 3) included the remaining five facts containing factors of 6s, 7s, and 8s.

Table 3
Multiplication Facts Used in the Study

MG 1	**MG 2**	**MG 3**
3 x 3 =	4 x 4 =	6 x 7 =
3 x 4 =	4 x 6 =	6 x 8 =
3 x 6 =	4 x 7 =	7 x 7 =
3 x 7 =	4 x 8 =	7 x 8 =
3 x 8 =	6 x 6 =	8 x 8 =

Measure of Memory Facts

A test was administered at the end of instruction for each memory group to measure student's progress during this project. The test was modeled after the multiplication test in Wood's (1998) study. The data obtained from these tests were used to answer both of the project's questions on the effectiveness of this mnemonic approach using pegwords paired with stories and illustrations: 1) Do these instructional strategies result in immediate improvement of accuracy in multiplication problems with each specific multiplication group? 2) Do students maintain high levels of accuracy with

previously taught multiplication facts; 3) Do students maintain accuracy on 2 and 4 week follow-up tests?

The tests consist of five rows of multiplication problems with six problems in each row. Each row contains three multiplication facts from the first five groups: (i.e. zeros, ones, twos, fives, nines), along with one fact from each of the three MG sets, for a total of 30 questions. To ensure random placement of the problems, the teacher used flashcards of all 100 multiplication facts to dictate which facts were used and the order that the facts were inserted into the test. The flashcards were separated into the four groups (prerequisites, MG 1, MG 2, and MG 3) and placed facedown. One card was drawn from each memory group and three cards were drawn from the prerequisite groups and then set aside until all facts in that group were used. This process was repeated for each of the five rows. When all flashcards in a group had been used, the flashcards were reshuffled and placed back into the pile facedown and the process began again.

The tests were scored using matching answer keys. Answer keys had the prerequisite facts and memory group sets marked for quick identification to the type of problem. Tests were scored by counting the number of problems answered correctly out of the total number of problems from each of the four groupings, (e.g., the number of problems from MG 2 answered correctly). The scores for each group were then transferred to the student's individual graphs.

Procedures for Teaching Memory Group Facts

Prior to beginning instruction on multiplication facts in the memory groups, students were taught the pegwords with their corresponding numeral (Table 4). Students

practiced the pegwords two ways: First, the teacher provided a flash card with the pegword and the student responded orally with the corresponding number (e.g. three-tree), and second, the teacher provided a flashcard with a number and the student orally responded with the corresponding pegword (e.g. door-four). After all students mastered identification of pegwords with corresponding numerals, then instruction of multiplication facts began with memory group set 1.

Table 4
Numeral with Pegword

2 = Shoe	6 = Chicks
3 = Tree	7 = Surfin'
4 = Door	8 = Skate
5 = Hive	9 = Sign

Students were taught strategies using a combination of teacher modeling, using manipulatives, and being provided pictures and mnemonic stories using materials from Multiplication in a Flash (Walker, 2009). The procedure for teaching each math fact included five steps. The first step was conceptual, using manipulatives and visual supports, the students modeled the multiplication facts as repeated addition. Second, students were shown pictures of the related pegwords and discussed the new pegword related to the product of the multiplication fact. For example, for 3 x 4, the students were shown pictures containing the numerals with pegwords related to the factors and introduced to the pegword (e.g., "elf" for 12). Then a story was presented incorporating the pegwords together. In this example an elf (12) needed a home so he finds a tree (3) and puts a door (4) on it for his home. Students were shown a picture representing the story. In the fourth step, students rehearsed the story to connect the pegwords in the story to the multiplication fact. In the fifth and final step students practiced. The teacher would

either orally present a fact, or use a flashcard prompting an oral or a written response from students using their response boards. After each student in the group provided at least three correct responses, the students then completed a worksheet containing a mixture of mastered facts and new facts. Scores from the worksheets served as a way to measure whether students had become proficient in answering the targeted multiplication fact accurately before they moved to instruction of next multiplication fact.

After students were taught the multiplication facts in a memory group, a multiplication test for that memory group (MG) set was administered. If two or more students did not score at the proficiency level of 80%, the group would receive further instruction and practice with the identified facts in the MG set. After re-teaching of the MG, students were given another multiplication test. When all students score 80% or better on the targeted memory group facts, instruction preceded to the multiplication facts in the next set of memory group facts.

Assessing Retention of Math Facts

A follow up multiplication test was administered to students two weeks after the post-test on all memory group facts. A second delayed test was administered four weeks later after the students returned from Christmas break. The scores were recorded as in previous tests.

Hypothesis

It was my belief that teaching these last fifteen multiplication facts using mnemonics would help these students increase accuracy with these multiplication facts.

The use of mnemonics has been effective in my classes when teaching content that is new (e.g., when using HOMES to help memorize the Great Lakes). The combination of visual supports paired with a story should help students remember each multiplication fact correctly. As students accuracy increases I expect to see an increase in the automaticity of students' responses.

RESULTS

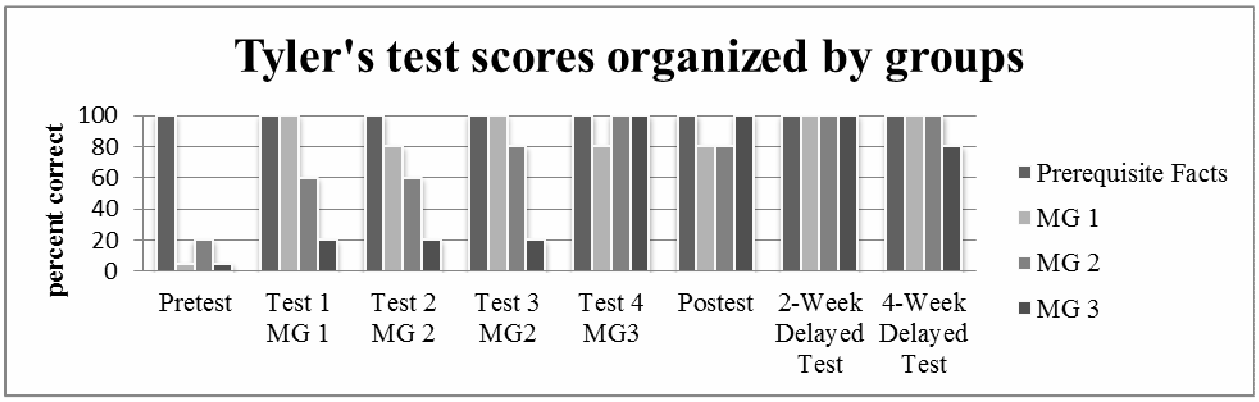
Students' Performance of Memory Group Facts.

Tyler

Tyler's performance on the prerequisite skills and the three memory groups for each test is presented in Figure 2. A comparison of Tyler's scores across the four categories show that he maintained a mastery level of 80% or better on facts learned while consistently scoring below 60% on untaught memory groups. On the pretest he scored 100% on the prerequisite facts, he did not answer any of the facts in either memory group one, nor memory group three, and answered only 1 fact correctly in memory group two. Substantial improvement was seen in in each of the three memory groups. Tyler's scores for MG 1, increase from 0% to 100% on test one, maintaining above 80% with a mean of 91% for the duration of the intervention. He showed improvement for MG 2, but his score of 60% on test two resulted in re-teaching and retesting. On test three, Tyler scored an 80% on MG 2 and again maintained above 80% with a mean of 92% for the duration of the intervention. MG 3 again showed substantial increases with scores of 20% or less before instruction to 100% on test four and maintaining above 80% with a mean of 95% correct for MG 3 for the duration of the

intervention. Tyler's scores suggest that using pegword instruction paired with stories and illustrations for multiplication instruction did produce significant improvement that was maintained after introduction to new facts.

Figure 2

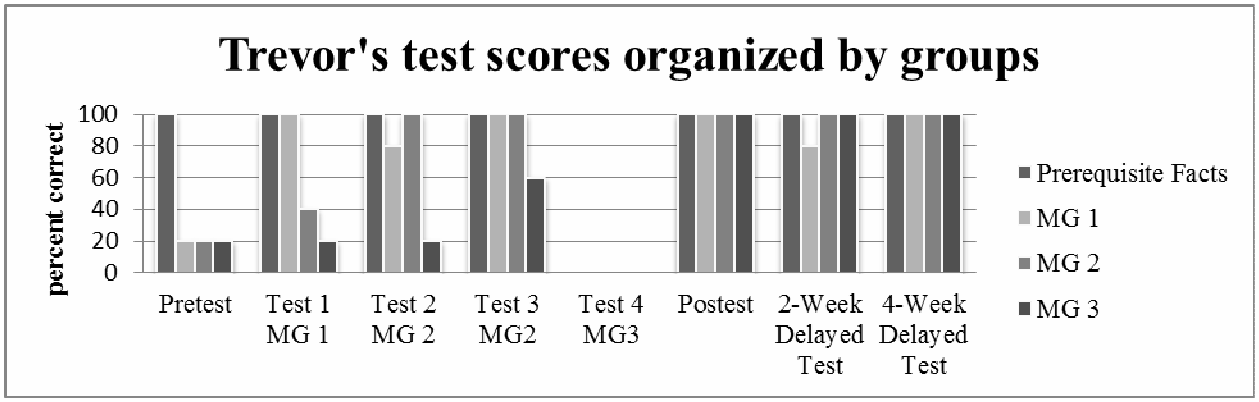


Trevor

Trevor's performance on the prerequisite skills and the three memory groups for each test is presented in Figure 3. A comparison of Trevor's scores across the four categories show that he maintained a mastery level of 80% or better on facts learned while consistently scoring below 60% on untaught memory groups. On the pretest he scored 100% on the prerequisite facts, and 20% on MG 1, MG 2, and MG 3. Trevor's scores for MG 1 increased from 20% to 100% on test one, maintaining above 80% with a mean of 93% correct for the duration of the intervention. He showed improvement for MG 2 which he increased from 20% to 100% on test two, maintaining 100% accuracy throughout intervention. Trevor was absent on the day that test 4 was administered at the end of MG 3 instruction but substantial increases were seen with MG 3 with scores of 20% or less before instruction to 100% on the posttest and maintained 100% accuracy throughout the intervention. Trevor's solid scores suggest that the use of pegword

instruction paired with stories and illustrations for multiplication instruction produced significant improvement that was maintained after introduction to new facts.

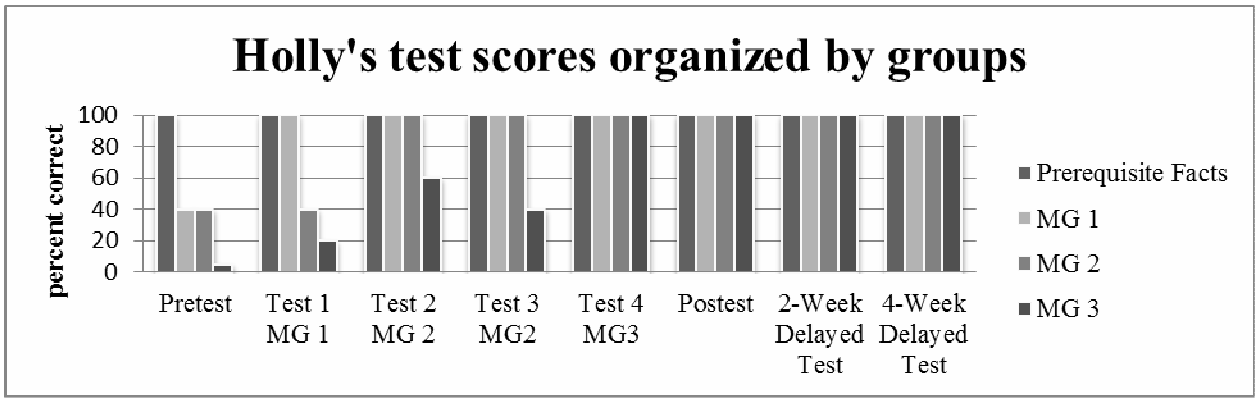
Figure 3



Holly

Holly's performance on the prerequisite skills along with the three memory groups for each test is presented in Figure 4. A comparison of Holly's scores across the four categories show that she maintained a mastery level of 100% on facts learned while consistently scoring below 60% on untaught memory facts. On the pretest she scored 100% on the prerequisite facts, a 20% on MG 1 and MG 2, and a 0% on MG 3. Holly's scores for MG 1 increased from 40% to 100% on test one and remained stable at 100% accuracy for the duration of the intervention. She showed similar increases for MG 2 and MG 3, which increased from 40% to 100% for MG 2 on test two, and from 40% to 100% for MG 3 on test four. Holly's solid scores suggest that the use of pegword instruction paired with stories and illustrations for multiplication instruction does produce significant improvement that was maintained after introduction to new facts.

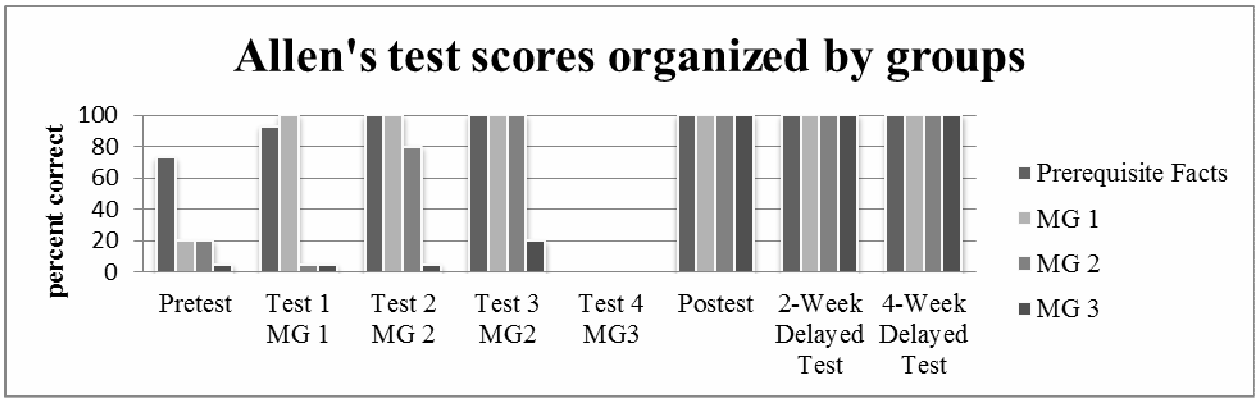
Figure 4



Allen

Allen's performance on the prerequisite skills and the three memory groups for each test is presented in Figure 5. A comparison of Allen's scores across the four categories show that he maintained a mastery level of 80% or better on facts learned while consistently scoring below 40% on untaught memory groups. On the pretest he scored 73% on the prerequisite facts, 20% on MG 1 and MG 2, and 0% on MG 3. Allen's scores for MG 1 increased from 20% to 100% on test one and he maintained 100% for the duration of the intervention. His score for MG 2 increased from 0% to 80% on test two and then continued to increase to 100% on test 3 while MG 2 was still the target group. He maintained 100% accuracy for MG 2 for the remainder of the intervention. Allen's mean scores for MG 3 before instruction was 5%. Allen was absent for the test following instruction for MG 3, on the posttest, Allen answered 100% correct for the targeted facts and maintained 100% for the remainder of the intervention. Allen's improvements were the largest of the students with scores for all learned facts maintaining a 100% accuracy. Again this suggests that pegword instruction paired with stories and illustrations for multiplication instruction produces significant improvement that is maintained after introduction to new facts.

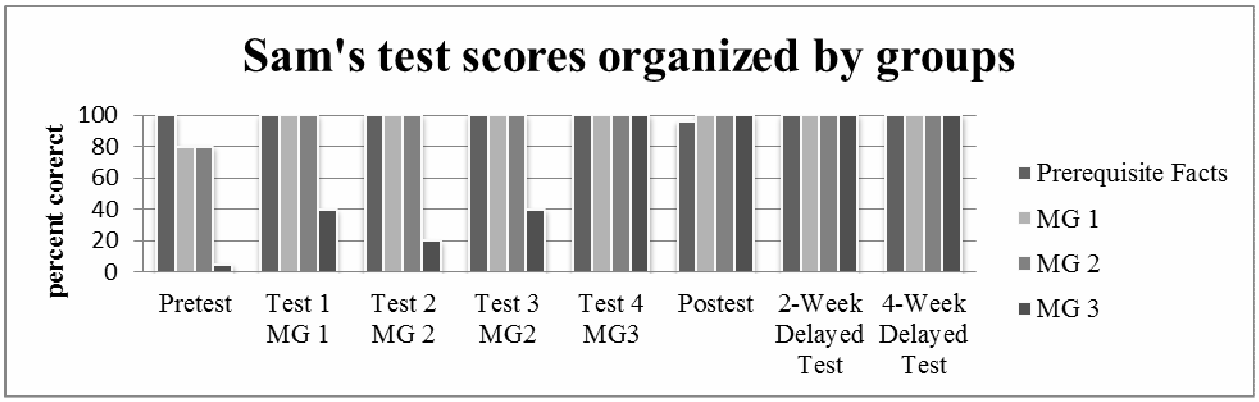
Figure 5



Sam

Sam's performance on the prerequisite skills along with the three memory groups for each test is presented in Figure 6. Comparisons of Sam's scores across the four categories show that he maintained a mastery level of 100% on facts learned. Sam's scores for the both MG 1 and MG 2 never fell below 80%. However his scores on MG 3 were consistently below 40% until he received instruction for that particular memory group when they increased to 100% on test four. His scores on MG 3 pegwords were maintained at 100% for the duration of the intervention. Even though Sam had higher initial scores to begin with, the immediate increase found in MG 3 would suggest that the use of pegword instruction paired with stories and illustrations for multiplication instruction produced significant improvement that was maintained after introduction to new facts.

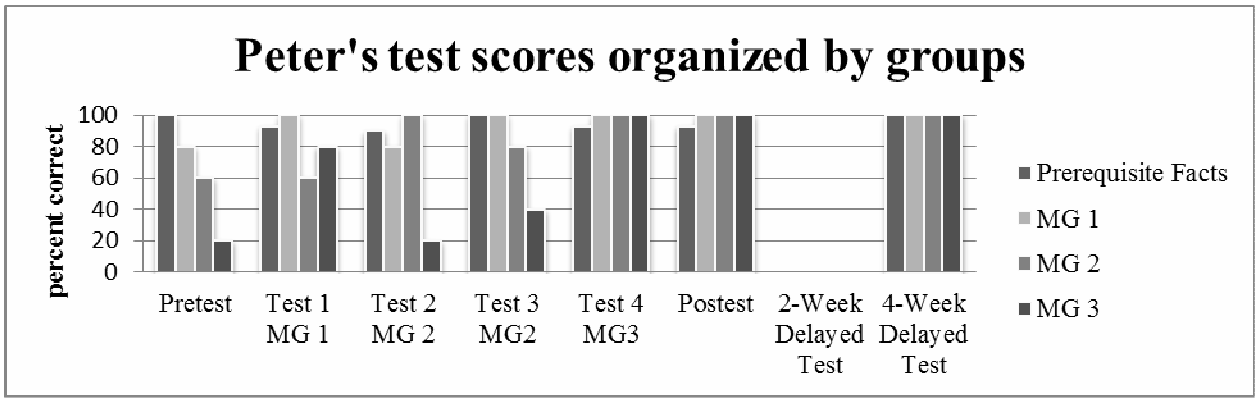
Figure 6



Peter

Peter's performance on the prerequisite skills along with the three memory groups for each test is presented in Figure 7. A comparison of Peter's scores across the four categories show that he maintained a mastery level of 100% on facts learned while consistently scoring below 60% on untaught memory groups. On the pretest he scored 100% on the prerequisite facts, 20% on MG 1 and MG 2, and 0% on MG 3. Peter's scores for MG 1 increased from 40% to 100% on test one and remained stable at 100% accuracy for the duration of the intervention. He showed similar increases for MG 2 and MG 3, which increased from 40% to 100% for MG 2 on test two, and from 40% to 100% for MG 3 on test four. Peter was absent for the two-week delayed test yet still maintained 100% for all groupings on the four-week delayed test. Peter's solid scores suggest that the use of pegword instruction paired with stories and illustrations for multiplication instruction produced significant improvement that was maintained after introduction to new facts.

Figure 7



Overall, these six students' responses to the intervention to master the fifteen targeted multiplication facts were quite similar. Prior to the intervention, the students' exposure and knowledge of these multiplication facts varied, yet after instruction was delivered for each memory group, the students demonstrated a similar response to the intervention with an immediate increase in the percent of facts answered correctly, with a mean increase of 68% after instruction. Figure 8 shows the increase in MG 3 most clearly.

Figure 8

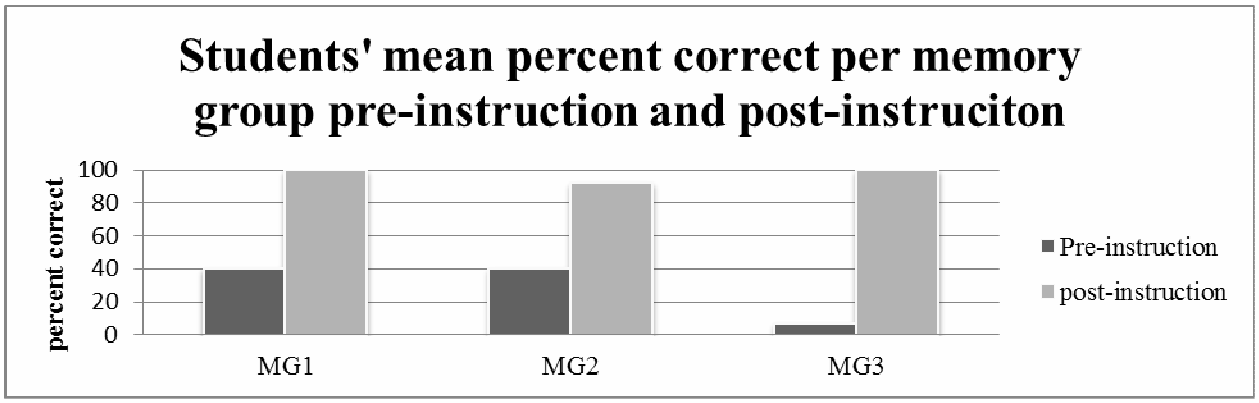
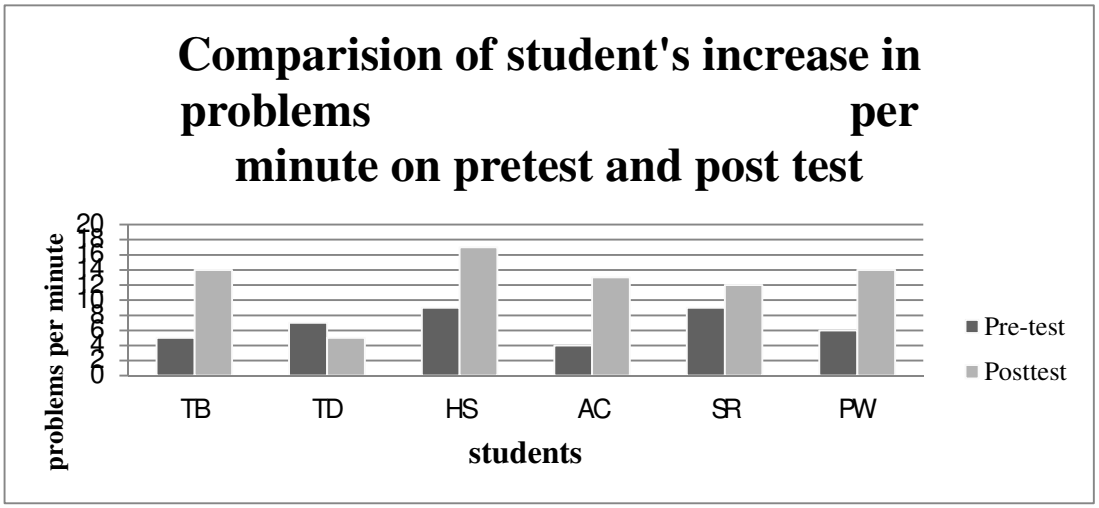


Figure 9 shows the increases in the students' rate of accurate responding on the multiplication tests. The amount of time it took students to complete each test was recorded along with the student's accuracy (i.e., the rate of problems completed per

minute). When comparing pretest and posttest data, five of the six students demonstrated positive increases in the rate of completing the tests (i.e., the time for test completion decreased).

Figure 9



Discussion

The findings from this project align with the Wood study. My students seem to enjoy the use of pegwords and it provided them tools for solving those facts that they had a difficult time remembering. The immediate increase in accuracy following instruction for these fifteen multiplication facts replicates the results from the Wood et al. (1998) study and shows a positive effect for the use of pegword instruction paired with the stories and illustrations and practice for teaching difficult multiplication facts. All students maintained 80% or better for the duration of the intervention, with introduction to new multiplication facts, and even after a 2-week break over Christmas.

The success of this intervention goes deeper than meaningful increases in the students' accuracy for answering multiplication facts. In addition to the quantitative data, observations from both regular education teachers and the special education teacher affirm the effectiveness of this intervention. The students' attitudes towards math have become considerably more positive. The students' appeared to be more excited as they realized they were mastering these multiplication facts. This was observed both during the time set up for the intervention as well as later in the day when the students received resource support on their grade level core concepts. For instance, during multiplication and division units, the students would more quickly solve problems during their independent work and would not rely on the multiplication chart in their folders. Students have been overheard exclaiming that they "got it" or "I don't need my chart". Further, students were overheard reciting pegwords when faced with multiplication facts embedded in more challenging multiplication and division problems.

Another instance in which the positive effects of this intervention were manifested was in the students' rate of completion on the tests. Four of the five students had accuracy increases of 8 and 9 problems per minute. Increasing students' rate was not a focus of the intervention and was not reinforced; only accuracy was reinforced. Yet as students' attitude and confidence improved, the "side effect" was an increase in fluency.

Lastly, it is important to note that there were some facts in which very few of the students appeared to use the pegword strategies but still benefitted from explicit teaching of the fact and the practice involved with the lesson, as with 3x3 and 4x4. What was it about these facts that enabled students to master them without the support of the pegwords? One possible explanation is that both facts are squares. Maybe students had

had more exposure to these facts from previous teachers or units and now, with explicit instruction and practice answering the facts associated with the lesson, the students were provided enough support to efficiently store and retrieve those facts. Other facts were observed to require the pegword support more frequently, especially those facts in memory group three. For facts 6x7, 7x7, and 8x7, students would recall the pegword associations more regularly. One student explained that "he always gets those facts mixed up but the pegwords help keep them straight now". This was the researchers hope and intent for using pegwords. Giving these students tools, strategies and supports to help them distinguish one fact from another may make them feel successful and more confident in their ability to solve multiplication problems.

What was it about this intervention that produced significant gains in accuracy and rate of multiplication facts answered? This intervention employed multiple components including grouping multiplication facts, using explicit instruction and plenty of practice along with the use of pegwords, stories, and pictures. Since these components were present during the entire intervention, it cannot be deducted that the use of pegwords was the independent variable that produced significant gains for these students. The use of pegwords was emphasized by the researcher primarily due to the novelty of its approach in mathematics; yet inferring a positive relationship between the use of pegwords and the increase in accuracy and rate is not scientifically justified. To truly know the effectiveness of using pegwords for teaching multiplication would require a carefully controlled parametric experiment, manipulating the use of each of these components. With that type of design, a positive relationship between the use of mnemonics and improved math performance could be established.

Conclusion

Finally, the combination of the components used in this project in conjunction with pegword instruction produced meaningful gains in the percent of multiplication facts answered correctly. Pairing numbers with pegwords with stories and pictures seems to provide students with mild to moderate disabilities the support necessary to more effectively store and retrieve multiplication facts. This project along with the Wood et al. (1998) and Greene (1999) studies provide examples of the potential effectiveness of multiplication interventions incorporating pegwords. A resource classroom would be an ideal setting for implementing this intervention based on the significant gains in accuracy and rate, the relative ease of implementation and the short length of time required for implantation.

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Appendix A

Explanation of Instruction Strategies on Prerequisite Multiplication Fact Groups

Teaching Strategies		
Groups (in order of sequence for intervention)	Explanation *Student determines if the multiplication fact contains*:	Example
Zeros	A zero as a factor, if so the product will always be zero.	3 x 0 = 0, 0 x 8 = 0, 5 x 0 = 0
Ones	A one as a factor, if so the product will be the other factor.	1 x 7 = 7, 4 x 1 = 4, 1 x 8 = 8
Doubles (twos)	A two as a factor, if so the student will pair a familiar object representing the algorithm to find the product.	2 x 4 = 8, a toy spider with two sets of four legs for 8 total legs. 9 x 2 = 18, an "18 wheeler" having two sets of nine wheels. 3 x 2 = 6, a "six pack of pop" two sets of three cans.
Fives	A five as a factor, if so the student will use "touch points" for the other factor while skip counting by fives to find product.	5 x 3 = 15, touch the three 3 times while counting by fives: five, ten, and fifteen. 8 x 5 = 40, touch the eight, 8 times while counting by fives: five, ten, fifteen, twenty, twenty-five, thirty, thirty-five, and forty.
Nines	A nine as a factor, if so the student will find the product by subtracting 1 from the factor that is not a nine, this digit is linked to another digit whose sum is 9.	9 x 7 = 63, seven minus one equals six, six goes in the "tens place" and three is linked with six for an answer of 63. 4 x 9 = 36, four minus one equals three, three goes in the "tens place" and six is linked to three for an answer of 36.

Appendix B Prerequisite Test

Name: **Prerequisite Fact Test A** **Score**_____

Find the product.

1. 1 × 6	2. 1 × 3	3. 3 × 2	4. 6 × 2	5. 9 × 5	6. 3 × 9
7. 2 × 4	8. 0 × 6	9. 2 × 9	10. 5 × 6	11. 8 × 5	12. 9 × 6
13. 1 × 8	14. 2 × 2	15. 2 × 5	16. 1 × 4	17. 0 × 0	18. 2 × 3
19. 4 × 5	20. 5 × 7	21. 2 × 7	22. 5 × 2	23. 5 × 4	24. 9 × 9
25. 0 × 3	26. 4 × 9	27. 7 × 5	28. 5 × 9	29. 6 × 9	30. 9 × 4
31. 5 × 8	32. 3 × 5	33. 9 × 1	34. 9 × 0	35. 9 × 8	36. 8 × 9
37. 1 × 7	38. 4 × 2	39. 8 × 2	40. 5 × 5	41. 2 × 6	42. 1 × 1
43. 2 × 1	44. 6 × 5	45. 7 × 2	46. 5 × 1	47. 2 × 8	48. 9 × 3
49. 9 × 7	50. 9 × 2	51. 4 × 0	52. 5 × 3	53. 7 × 9	54. 0 × 2

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Appendix C Multiplication Fact test

Name: **Multiplication Fact Test A** **Score**_____

Find the product.

1. 3 × 5	2. 7 × 8	3. 2 × 3	4. 3 × 3	5. 5 × 6	6. 4 × 8
7. 9 × 8	8. 7 × 3	9. 4 × 7	10. 2 × 2	11. 5 × 8	12. 7 × 7
13. 5 × 4	14. 6 × 7	15. 0 × 9	16. 2 × 9	17. 3 × 8	18. 6 × 6
19. 4 × 4	20. 9 × 3	21. 6 × 3	22. 1 × 5	23. 5 × 7	24. 8 × 8
25. 2 × 5	26. 1 × 3	27. 3 × 4	28. 4 × 6	29. 8 × 6	30. 5 × 5

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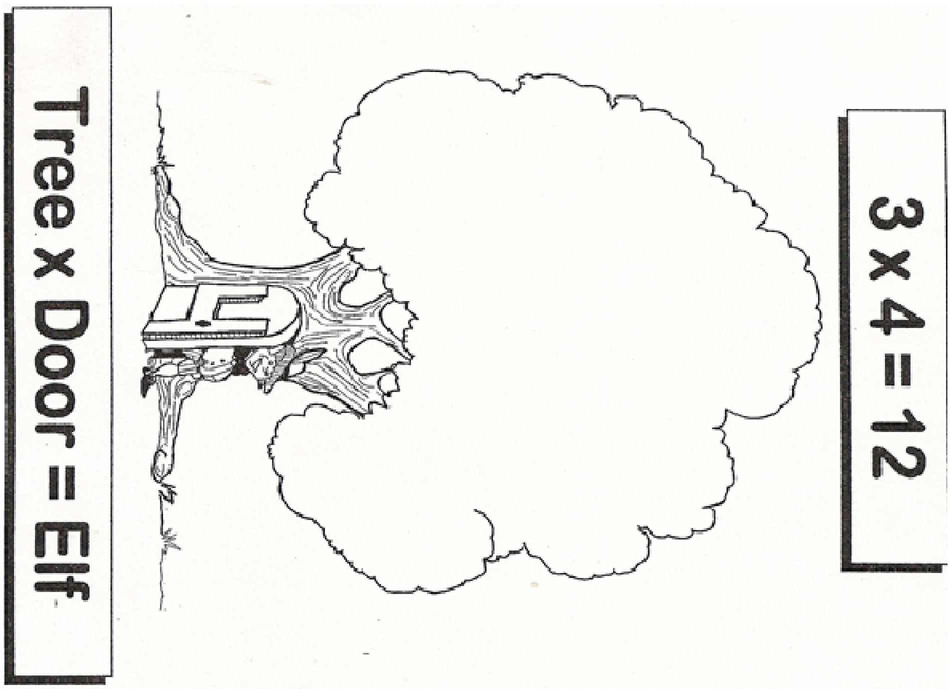
Appendix C Example of Mnemonic story with visual support



Once there was a homeless elf who loved the forest. All day he would wander and play among the tall trees. At night he would lie under the stars and the trees he loved so well. Sometimes he would get cold and wet. He needed a shelter. One day he thought of a great solution. He found a big hollow TREE (3), added a little DOOR (4), and had a cozy ELF (12) home.