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The effects of a taped-problems intervention on multiplication fact fluency of fourth grade title I math students

Matthew Stadler

The Effects of a Taped-Problems Intervention on Multiplication Fact Fluency of Fourth Grade Title I Math Students

Matthew Stadler

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Action Research Master's Thesis Approval

As the advisor for Matthew Stadler, on behalf of the Masters of Urban Education Program in the School of Education, in the College of Education and Leadership at Cardinal Stritch University, I affirm that the action research master's thesis meets the expectations and academic requirements for the degree of Masters of Arts in Teaching.

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Advisor Approval Date

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ABSTRACT

The purpose of this action research study was to increase multiplication fact fluency for a small class of fourth grade students by implementing an efficient intervention model. The research question was: What are the effects of a Taped-Problems (TP) intervention on multiplication fact fluency of fourth grade Title I math students? This study applied a quantitative, quasiexperimental, one-group pretest-posttest design. To test the effect TP intervention had on student multiplication fact fluency, mean DCM scores on baseline assessment probes were compared to mean DCM scores on maintenance assessment probes with a two-tailed dependent *t*-test. For two of the three problem sets, the maintenance mean DCM scores increased significantly over the baseline mean DCM scores. Furthermore, analysis of individual student mean DCM scores indicated an increase from either frustration level to instructional level or instructional level to mastery level (Deno & Mirkin, 1977). The data moderately supported the hypothesis that TP intervention affected student multiplication fact fluency. Based on the results of this study, further research would be merited on examining the number of intervention sessions as related to sustained maintenance DCM scores. It would also be advantageous for future research to investigate the effects of efficiency modifications such as training students or developing computer software for independent administration of the TP intervention.

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CHAPTER ONE: INTRODUCTION

It has been my experience when a timed multiplication facts test is presented in the classroom, there are always a handful of students eager to demonstrate their skills. However, all too often many use their fingers to skip count, reply with a stressed “I don’t know” look, or utilize both ineffective strategies. The importance of math fluency skills was observed in the classroom of a fifth grade homeroom teacher as she taught multi-digit multiplication to a remedial level math class. At least half of the students struggled to answer multiplication facts correctly and, therefore, had a very difficult time completing the multi-digit multiplication classwork. In my school, students who did not memorize all facts by the end of third grade were unfortunately left to learn them on their own in fourth and fifth grade. One fourth grade teacher was quoted, “We do not have enough classroom time to re-teach the basic multiplication facts. The only thing we can do is attempt to motivate the students enough to push themselves to learn [multiplication facts] on their own at home. Many achieve this, but of course, there are always some who do not.”

Title I teachers are contracted to provide supplemental instruction to close the achievement gap between students and their classmates. During my six years of teaching Title I math to elementary students, I have found that the gap created from multiplication facts proved difficult to bridge, despite a variety of best efforts. Strategies utilized to provide practice answering math facts have ranged from watching videos and singing songs, to crafting art projects and playing games. The methods were designed to leverage learning styles and assisted students to make gains in fact fluency, but often required excessive instructional time that was precious and limited. A more effective, research-based intervention with a higher learning rate was required, thus, the impetus of this study.

Background of the Study

By the end of third grade, the Common Core State Standard 3.OA.C.7 (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) stated that students should fluently multiply and divide within 100 and know all products of two one-digit numbers from memory. The ability to recall math facts quickly and accurately has been determined to be a significant contributing factor in the development of advanced cognitive strategies and solving complex arithmetic problems as students matriculate into higher grade levels (Carr & Alexeev, 2011; Vasilyeva, Laski, & Shen, 2015). However, memorizing the basic multiplication tables can be overwhelming and very difficult for students. DeVisscher and Noel (2014) demonstrated a relationship between low arithmetical fluency and a hypersensitivity-to-interference in students. Retrieval difficulties could also stem from severe memory deficits (Lerner, 2003). At the end of the 2015-2016 school year, after six months of learning and practicing multiplication facts, 74% of the 23 third graders in the low-level math class of my school had not mastered all of the facts from zero to ten. Of those students, four had yet to master half of the multiplication facts.

While searching scholastic databases a number of research-based interventions regarding arithmetic fluency were presented, Incremental Rehearsal (Burns, 2005), Behavioral Self-Management (McDougall & Brady, 1998), Cover, Copy, and Compare (Skinner, McLaughlin & Logan, 1997), and Taped-Problems (McCallum, Skinner, Turner, & Saecker, 2006). Taped Problems (TP) was chosen based on the recentness of the study. Furthermore, Poncy, Skinner, and McCallum (2012) demonstrated that a TP intervention had a higher learning rate than Cover, Copy, and Compare. The benefits of utilizing an efficient intervention was twofold in that instruction time was minimized while learning was maximized, and it can quickly be determined if a student needs were not being met.

The Taped Problems intervention was modified from Freeman and McLaughlin's (1984) taped-words intervention, used to increase word list reading fluency. McCallum, Skinner, and Hutchins (2004) developed the intervention to enhance division fact fluency for a single student. McCallum, Skinner, Turner, and Saecker (2006) then determined the intervention could be successfully applied class-wide and McCallum and Schmitt (2011) determined TP was effective for students with intellectual disabilities. Subsequent component analyses enabled modification to the TP intervention to be as efficient as possible. Bliss et al. (2010) determined that an additional daily assessment did not demonstrate a significant difference when removed. Poncy, Jaspers, Hansmann, Bui, and Matthew (2015) determined that a time delay within the intervention also did not demonstrate a significant difference when removed. Finally, McCallum, Schmitt, Schneider, Rezzetano, and Skinner (2010) determined an added group reward demonstrates no significant difference when compared to the intervention with no reward.

Overview of the Study and Timeline

The purpose of this action research study was to increase multiplication fact fluency for a small class of fourth grade students by implementing an efficient intervention model. The research question was: What are the effects of a Taped-Problems (TP) intervention on multiplication fact fluency of fourth grade Title I math students?

The research design was a quantitative, quasiexperimental, one-group pretest-posttest design. The independent variable was a TP intervention. Basic multiplication facts two through nine, excluding multiples of zero and one, were divided into three sets, A, B, and C, of 12 problems each (see Appendix A). During an intervention session students listened to an audio recording of one set of problems and the answers. Students concurrently read a printed copy (see Appendix B) of the problems without answers and were instructed to “beat the recording” by writing the correct answer to each problem before it was spoken on the recording. The dependent variable was digits correct per minute (DCM) measured on researcher modified assessment probes (see Appendix C) consisting of 48 multiplication problems. Based on Deno and Merkin’s (1977) scoring procedure, a two-digit answer could receive 0-2 points, depending on the placement of each digit. For example, with the problem 3x5 =__, an answer of 45 would receive 2 points because both digits were in the correct place. An answer of 15, or 42 would receive 1 point. An answer of 10 or 54 would receive 0 points. Assessment probes were administered before, during, and after the intervention phase for each problem set. The TP intervention and assessments for all three problem sets were conducted during the students’ Title I Math class over the course of seven weeks during the fourth quarter of the 2015-2016 school year.

Summary Conclusion

The study was conducted in an urban Muslim school located in the Midwest. There were 762 students enrolled in K5 through twelfth grade. The student population was 43% boys and 57% girls. Ethnicity demographics consisted of 53.5% Caucasian, 31.1% Asian, 14.7% African American, and 0.7% were two or more ethnicities. The sample consisted of five fourth grade students from a Title I math classroom during the fourth quarter of the school year. Student ages ranged from nine to eleven years, with a mean age of 9.8 years. Four were male and one was female. Two students were African-American and three were Asian. Three students spoke English as a second language. All students were identified as requiring Title I math services three times per week based on standardized tests scores and informal assessments administered during the first quarter of fourth grade. The mean mathematics RIT score for these students on the Fall

2015-16 Measures of Academic Progress test (Northwest Evaluation Association, 2012) was 179.6 compared to the Norm Grade Level mean RIT of 202. Baseline data from this study placed four students in the frustration level and one in the instructional level regarding multiplication math fluency (Deno & Merkin, 1977).

Definitions

Fluency: Rapid and accurate responses (McCallum, Skinner, Turner, & Saecker, 2016)

Interference: Overlap between previously memorized items and new ones (Visscher & Noël, 2014). For example, 6x7=42 and 6x8=48 have a common factor as well as a common tens place in the product.

Taped Problems Intervention: Students listen to audio recordings of math facts followed by the answers to the math facts. Students are directed to write the answer on a corresponding worksheet before hearing the correct answer spoken on the recording. (McCallum, E., Skinner, C., Turner, H., & Saecker, L., 2006)

Learning rate: The most learning in the least amount of instructional time (Poncy, Skinner & McCallum, 2012)

CHAPTER TWO: LITERATURE REVIEW

The purpose of this action research study was to increase multiplication fact fluency for a small class of fourth grade students by implementing an efficient intervention model. The ability to recall math facts quickly and accurately has been determined to be a significant contributing factor in the development of advanced cognitive strategies and solving complex arithmetic problems as students matriculate into higher grade levels (Carr & Alexeev, 2011; Vasilyeva, Laski, & Shen, 2015). The research question was: What are the effects of a Taped Problems (TP) intervention on multiplication fact fluency of fourth grade Title I math students? The research design was a quantitative, quasiexperimental, one-group pretest-posttest design. The independent variable was a TP intervention. Students listened to a series of multiplication fact problems (see Appendix A) and answers read on an audio recording. Students concurrently read a printed copy of the problems without answers (see Appendix B) and were instructed to "beat the recording" by writing the correct answer to each problem before it was spoken on the recording. The dependent variable was digits correct per minute (DCM) measured on researcher modified assessment probes (see Appendix C), consisting of 48 multiplication problems, administered at various intervals during the study. Based on Deno and Merkin's (1977) scoring procedure, a two-digit answer could receive 0-2 points, depending on the placement of each digit. For example, with the problem 3x5 =__, an answer of 45 would receive 2 points because both digits were in the correct place. An answer of 15, or 42 would receive 1 point. An answer of 10 or 54 would receive 0 points.

The literature review consisted of eight studies related to TP interventions within the context of math fluency. The studies were divided into two subcategories. The first category contained studies regarding the TP intervention, its components, and its effective scope. The second category included studies that focused on the attributes of students that either enhance or diminish their math fluency capabilities.

Research Studying TP Interventions

The studies (Bliss et al., 2010; McCallum & Schmitt, 2011; McCallum, Schmitt, Schneider, & Rezzetano, 2010; McCallum, Skinner, Turner, & Saecker, 2006; Poncy, Jaspers, Hansmann, Bui, & Matthew, 2015; Poncy, Skinner, & McCallum, 2012) in this section focused on the TP intervention. Four analyzed various components against controls with the intent to create a more efficient or effective intervention design. A fifth compared TP to an alternate intervention while the sixth investigated the effectiveness of the TP on a student with intellectual disabilities.

McCallum, Skinner, Turner, and Saecker (2006) adapted an individual TP intervention for use on a class-wide basis. While much class time and teacher effort is focused on the memorization of math facts, many students have difficulty reaching fluency by responding accurately and rapidly. Students who have obtained math fact fluency are able to focus their energy toward more complex mathematical problems, while students without fluency must expend more effort to complete complex problems. TP interventions had been previously utilized to increase word list reading fluency as well as division fact fluency in a single student. The research question was: What are the effects of class-wide TP on multiplication fact fluency?

The researchers utilized a quantitative quasiexperimental multiple-probes-across-tasks design. The sample consisted of 18 third grade students eight and nine years old from a general education classroom. Ten students were male and eight female. Eleven students were Caucasian, five African American, and two Hispanic. Students ranged in performance ability, yet none had been identified as requiring special education classes.

The independent variable was a taped-problems intervention with a varying time delay. Basic multiplication facts two through nine (Multiples of zero and one were excluded) were divided into three sets, A, B, and C, of 12 problems. An audiotape was created for each set. On the tape, the 12 problems were read aloud with a varying time delay between each problem and its answer. Each set was read four times, and for each reading the order of problems was randomized. The first read-through had no delay, the second read-through had a four second delay, and the third and fourth read-throughs both had a two second delay. Students listened to the tape while attempting to write the answer on a corresponding worksheet before it was provided. Each session included the playing of all four read-throughs of a set. The dependent variable was digits correct per minute (DCM) measured on assessment probes. A two-digit answer received 0-2 points, depending on the placement of each digit.

This study included three phases, a baseline phase, an intervention phase, and a maintenance phase. The baseline phase, which was utilized to establish a starting point of student performance, involved the administration of assessments A, B, and C each day, for three days. The intervention phase began the following week, and was three weeks in duration. Each week the TP intervention targeted a single set of problems for four consecutive days: Set A the first week, Set B the second week, and Set C the third week. An intervention session consisted of a delayed assessment, the TP intervention, and an immediate assessment, all specific for the targeted set for that week. The delayed assessment, collected at least one day after a previous day’s intervention session, served as the dependent variable. The immediate assessment served to evaluate the immediate effects of the intervention. The following week, prior to beginning the intervention for the next set of problems, assessments for all three sets were administered. Any assessment for a set of problems administered after the set's intervention had ceased was considered part of the maintenance phase.

The daily DCM mean for each assessment, delayed and immediate, within each problem set was graphed for visual analysis. Although data points for the delayed assessments were typically lower than the immediate assessments for the same day, both assessments had a similar increasing slope of DCM during the intervention phase for all three sets of problems. DCM from the maintenance phase slightly decreased relative to the intervention phase, but demonstrated sustained increases over the baseline DCM.

DCM means and standard deviations during each phase for Sets A, B, and C were utilized to calculate effect sizes, as described by Busk & Marascuilo (1992). For Set A, the intervention phase mean for both immediate (*M*=13.6, *SD*=3.2) and delayed (*M*=13.3, *SD*=3.3) more than doubled from the baseline mean (*M*=6.5, *SD*=1.3). Effect sizes demonstrated large increases in DCM for both immediate (effect size = 1.09) and delayed (effect size = 1.05) assessments. For Set B, the intervention phase mean for both immediate (*M*=14.9, *SD*=2.8) and delayed (*M*=14.6, *SD*=2.2) nearly doubled from the baseline mean (*M*=7.5, *SD*=0.7). Effect sizes demonstrated large increases in DCM for both immediate (effect size = 0.99) and delayed (effect size = 0.95) assessments. For Set C, the intervention phase mean for both immediate (*M*=16.4, *SD*=2.8) and delayed (*M*=14.2, *SD*=3.7) increased from the baseline mean (*M*=9.1, *SD*=0.6). Effect sizes demonstrated large increases in DCM for both immediate (effect size = 1.6) and delayed (effect size = 0.87) assessments.

The results of this study indicated that a TP intervention was an effective class-wide tool for increasing multiplication fluency. Visual and effect size analyses suggested that the intervention caused an immediate and steady increase in the class's mean DCM score which were maintained over weeks. The majority of students demonstrated gains in fact fluency, and continuing the intervention for a longer period of time may lead to more students reaching mastery.

Bliss et al. (2010) also revisited TP intervention to specifically evaluate the immediate response component of the intervention. TP interventions were designed to include two assessments after each intervention session, one immediately preceding the intervention and a delayed assessment that was administered at least one day afterward. The delayed assessment was utilized to measure the treatment effects of the intervention, while the additional immediate assessment (AIA) was only utilized to provide students an additional opportunity to respond independently from the auditory corrective prompts to enhance fluency. To minimize the amount of instructional time for TP intervention this study was designed to determine whether the AIA enhanced fluency development. The research question was: Does the inclusion of an AIA enhance math fact fluency development of a TP intervention?

The sample consisted of six students, three boys and three girls, from a fifth-grade math class in an elementary school with 80% students qualifying for free or reduced-price meals. Two students were African American, three Caucasian, and one was Hispanic and spoke English as a second language. Based on achievement tests and teacher referrals, the students were placed in a leveled math class at the lowest remedial level.

The researchers utilized an adapted alternating treatments design. The independent variable was the removal of the AIA component from a TP intervention. This was compared to a TP intervention with AIA (TP+AIA). The dependent variable was digits correct per minute (DCM) calculated by doubling the digits correct on 30-second delayed assessment probes. A two-digit answer received 0-2 points, depending on the placement of each digit.

Basic multiplication facts were divided into three sets (A, B, and C) of 12 problems each. Multiples of zero and one were excluded. Audiotapes were created for Sets B and C. On the tape, the 12 problems were read aloud with a varying time delay between each problem and its answer. Each set was read three times, and for each reading the order of problems was randomized. The first read-through had no delay, the second read-through had a two second delay, and the third read-throughs had a one second delay. Students listened to the tape while attempting to write the answer on a corresponding worksheet before it was provided. A TP intervention session included the playing of all three read-throughs of a set and was approximately eight to ten minutes in duration. Assessment probes for each problem set were also created. Each probe included the 12 problems of that set in random order repeated three times for 36 problems.

A baseline phase began with assessment probes for all three problem sets being administered on four consecutive days. Each assessment session was approximately four minutes. On the fourth day, the intervention sessions began immediately following the final baseline assessment. Problem Set B was randomly assigned to the TP condition, Set C assigned to TP + AIA, and Set A assigned to control without intervention. Intervention sessions alternated daily, with Problem Set B targeted on the first day, Set C on the second, and so on. Delayed assessment probes for all three problem sets were administered the following day just prior to the next intervention session. Immediate assessment probes were only administered after intervention sessions for Problem Set C (TP + AIA). Each intervention type, TP and TP + AIA, was conducted six times. The study was 17 days in duration.

Descriptive statistics were utilized to analyze and compare individual student DCM mean scores and mean increases from baseline to intervention phases across sets. Mean increases for

Set A (control) ranged from -1.53 DCM (Baseline *M*=36.67, Intervention *M*=35.14) to 11.35 DCM (Baseline *M*=34.50, Intervention *M*=45.85). Mean increases for Set B (TP only) ranged from 3.14 DCM (Baseline *M*=46.00, Intervention *M*=49.14) to 19.40 DCM (Baseline *M*=32.00, Intervention *M*=51.40). Mean increases for Set C (TP+AIA) ranged from 2.76 (Baseline *M*=48.67, Intervention *M*=51.43) to 24.87 (Baseline *M*=38.00, Intervention *M*=62.87). Student individual means were plotted on a line graph. Visual analysis of individual means demonstrate increasing baseline trends, high levels of within-phase/within series variability and no clear trends during baseline and intervention phases.

The results of this study varied across students. Two students demonstrated gains of 10 DCM greater for TP + AIA intervention sessions than TP sessions without AIA. Conversely, one student demonstrated gains of 6 DCM greater for TP intervention sessions without AIA than with AIA. Three students demonstrated similar gains across the two interventions. This variability suggested that AIA can enhance fluency but is not effective across students and further evaluation of the AIA component is necessary.

Similarly, Poncy, Jaspers, Hansmann, Bui, and Matthew (2015) analyzed the length of time delay component of the TP intervention. Audio recordings utilized for TP interventions were designed to have a short delay (e.g., two seconds) between a math fact problem and its answer. The delay was provided to encourage students to actively respond to each problem. However, the instructional time required for an intervention to be effective was an important consideration for teachers. Eliminating the delay would decrease time needed to conduct a TP intervention. The research question was: Will a no time delay condition for a TP intervention result in a higher learning rate of addition math facts than a two second delay condition?

The sample consisted of 20 students from a general education second-grade classroom in the Midwest with 30% of the participating students receiving free or reduced-price lunch. Nine were male and eleven female, ranging in ages from seven to nine years (M=7.8 years). Seventeen were Caucasian and three Hispanic. None of the participants were receiving special education services.

The researchers utilized an alternating treatments design. The independent variable was the evaluation and comparison of three conditions: TP with two second delay, TP with no delay, and control condition. The dependent variable was digits correct per minute (DCPM) measured on assessment probes. A two-digit answer received 0-2 points, depending on the placement of each digit.

Basic addition facts were divided into three sets (A, B, and C) of 12 problems. CDs were created for each set. On the CD, the 12 problems were read aloud with or without a time delay between each problem and its answer. Each set was read four times, and for each reading the order of problems was randomized. Students listened to the CD while attempting to write the answer on a corresponding worksheet before it was provided. Set A was paired with the two second delay condition and were approximately 4.5 minutes in duration per intervention session. Set B was paired with the no delay condition and were approximately three minutes in duration per intervention session. Set C was assigned as the control. Assessment probes for each problem set were also created. Each probe included the 12 problems of that set in random order repeated four times for 48 problems.

A baseline phase began with assessment probes for all three problem sets being administered on six consecutive days. On the seventh day the intervention phase began and continued for 12 days. Each morning, assessment probes for all three problem sets were administered to collect DCPM data. Interventions for Problem Sets A and B alternated with one being conducted in the morning immediately following the assessment probes, and the other intervention being implemented in the afternoon. To compare the learning rates of TP with and without the two second delay time needed to remain constant. However, each no delay session was approximately 1.5 minutes shorter than each two second delay session, therefore a five day replication phase followed the intervention phase to equate instructional time. During the replication phase assessment probes continued to be administered in the morning. The no delay intervention of Problem Set B also continued, alternating morning and afternoons, but the two second delay with Problem Set A was terminated. The additional sessions allowed the no delay intervention to equate total instructional time with the two second delay intervention. Furthermore, Problem Set C, the former control, was paired with the two second delay intervention. This pairing allowed for continuity in alternating morning and afternoon sessions, while providing the class with intervention opportunities across all 36 problems. Once the replication phase ended, a final assessment session for all three problem sets was administered one week later to collect maintenance data.

Visual analysis of data graphed by session was utilized to compare the daily mean DCPM across baseline, intervention, replication, and maintenance phases for each problem set. During the intervention and replication phases both Problem Set A (two second delay) and Problem Set B (no delay) demonstrated similar increasing trends when compared with Problem Set C (control). Effect sizes were calculated utilizing a mean phase difference method. Effect size results of baseline to the intervention phase was 13.27 DCPM for Set A, 11.37 DCPM for Set B, and 2.58 DCPM for Set C. These calculations support the visual analysis in that both TP conditions resulted in similar DCPM gains.

Descriptive statistics were utilized to analyze and compare DCPM mean scores of baseline data and the final three intervention data points across sets. The difference in classroom mean between scores for Set B (*M*=23.5) were greater than both Set A (*M*=15.3) and Set C (*M*=6.7). It should be noted that Set B had five additional intervention sessions than Set A to equate instructional time. Visual analysis of data graphed by instructional minutes was utilized to investigate learning rate. The no delay condition achieved levels of DCPM in 36 minutes of total instruction that were similar to levels of DCPM the two second delay condition achieved in 51 minutes of total intervention.

The results of this study suggested that the no delay condition in a TP intervention was more efficient in increasing math fact fluency than the two second condition, utilizing approximately 33% less time to achieve similar DCPM gains. However, once the two second delay condition was removed from Problem Set A, the DCPM continued to increase during the replication phase indicating an undetected threat such as multiple treatment interference.

McCallum, Schmitt, Schneider, and Rezzetano (2010) likewise revisited TP intervention to determine if adding rewards as an incentive for improved scores on assessments would increase performance. In a class-wide setting, the researchers determined it was difficult for educators to ensure that each student was attempting to write answers before it was heard on the tape, or if they were waiting until after it was heard. The latter behavior may be detrimental to the effectiveness of the TP intervention. The research question was: Is there a significant impact in effectiveness of class-wide TP intervention in promoting math fact fluency when utilizing a reward system?

The sample consisted of 40 African-American students from two second-grade general education classrooms in an urban charter school. Students ranged in performance abilities, however none were identified as requiring math special education services. Additional demographic information was not provided.

The researchers utilized a quantitative quasiexperimental between-groups pretest posttest design. The independent variable was the inclusion of a class-wide reward, such as extra recess time, if the class's mean score increased by one digit from the previous intervention day. The TP intervention was administered to both classrooms during nine days, but only one classroom received the incentive contingency. The dependent measure was digits correct per two minutes (DC2M) on timed assessment probes. A two-digit answer received 0-2 points, depending on the placement of each digit.

Basic subtraction facts one to nine were compiled into set of 36 problems. CDs were created on which each problem was read aloud with a two second delay between a problem and its answer. On each CD the set was read twice for 72 problems, each time in a randomized order. Students listened to the CD while attempting to write the answer on a matching worksheet before it was read aloud. Assessment probes were also created that contained the 36 problems repeated twice for a total of 72 problems.

Classroom A received only the TP intervention while classroom B received TP with an added group reward contingency. Both classrooms were led through three phases: baseline, intervention, and posttest. The baseline phase involved the administration of an assessment probe on three consecutive days to establish a baseline of student performance. The intervention phase involved nine sessions each held on consecutive school days. An intervention session consisted of a delayed assessment (with exception to the first session), the TP intervention, and an immediate assessment. The delayed assessment, collected at least one day after a previous day's intervention session, served as the dependent variable. The immediate assessment served to evaluate the immediate effects of the intervention. The posttest phase immediately followed removal of the TP intervention, and consisted of a timed assessment probe administered once per week for three weeks.

Effectiveness between classrooms was compared using statistical and visual analyses. Pre and posttest scores were compared utilizing paired samples *t*-tests.

Visual analysis of time-series graphs was utilized to compare the daily mean DC2M of both classrooms across baseline, intervention, and posttest phases. For both classrooms, immediate and delayed assessments demonstrated similar improvements and slopes throughout the intervention phase. This improvement even continued into the posttest phase for both classrooms.

A paired-samples *t*-test was conducted to determine if the posttest scores were significantly different from pretest scores. Results indicated that the intervention was effective in both classrooms. The mean posttest performance of classroom A (M=42.50, SD=16.13) was significantly greater than the mean pretest performance (M=21.90, SD=8.84), $t(19)=-9.18$, $p<.001$. The standardized effect size value for this paired samples *t*-test was high, d=2.05. The mean posttest performance of classroom B (M=38.24, SD=15.43) was also significantly greater than the mean pretest performance (M=18.15, SD=7.70) $t(16)=-8.55$, $p<.001$. Again, the standardized effect size value was high, d=2.08.

Finally, to determine if rewards resulted in greater DC2M improvement, a one-way ANCOVA was conducted. The effect of the covariate was not significant, requiring an independent samples *t*-test. Results determined that improvements in classroom B (M=20.09, SD=9.69) were not significantly greater than improvements in classroom A (M=20.60, SD=10.04), $t(35)=.16$, p=.88.

The results of this study indicated that while both rewarded and non-rewarded classrooms subtraction fact fluency significantly increased, there was no difference in student gains between classrooms. Anecdotal evidence suggested that factors such as intrinsic rewards (beating the CD) or competition between peers might be sufficient motivation for students to follow targeted procedures to improve performance.

As opposed to evaluating a component of TP, Poncy, Skinner, and McCallum (2012) compared the impact TP and Cover, Copy, and Compare (CCC) had on students' subtraction fact fluency in a class-wide setting. Both interventions had empirically demonstrated to increase students' math fact fluency, yet the learning rate of these interventions had not been evaluated when instructional time was held constant and were conducted in a class-wide setting. The research question was: Is there a difference in learning rate of class-wide CCC and class-wide TP in promoting math-fact fluency?

The sample consisted of 20 third-grade students from a general education classroom in north-central Iowa. Eleven students were girls and nine were boys, ranging in ages eight to ten. Seventeen were Caucasian, two Latino, and one Asian. None of the students received special education services in mathematics.

The researchers utilized a quantitative alternating treatments design to investigate and compare the two interventions while simultaneously implementing a control condition. The independent variables were the CCC and the TP interventions, each for a different set of subtraction facts. The dependent variable was digits correct per minute (DCM) on one-minute assessment probes for each of the sets of subtraction facts. A third set of facts was also assessed without intervention as a control.

Basic subtraction facts with minuends 18 through 4 and subtrahends 2 through 9 were divided into three sets and randomly assigned to each intervention and control. The control was assigned Set A, the CCC intervention was assigned Set B, and the TP intervention was assigned Set C. For the TP intervention, the subtraction facts were read aloud with a two-second delay between each problem and its answer. The set was read repeatedly, each time in a random order, during six minutes for approximately 72 problems. Students listened to the tape while attempting to write the answer before it was provided on a corresponding worksheet. For the CCC intervention, the subtraction facts were transcribed into fact family triangles on a worksheet with two empty boxes to the right of each triangle. For six minutes, students read the printed fact family, covered it, and wrote the two reciprocal subtraction facts that corresponded to the fact family triangle into the empty boxes. Then the student would uncover the fact family triangle to check the accuracy. If the answers were accurate, the student began the steps again with the next fact family triangle. If the answers were inaccurate, the student would mark an “X” through the incorrect subtraction fact and write the correct fact. If a student finished the intervention worksheet, he/she would raise his/her hand to receive a new worksheet. Assessment probes for each problem set were also created. Each probe included the subtraction problems of that set in random order repeated twice.

A baseline phase began with assessment probes for all three problem sets being administered on four consecutive days. On the fifth day each of the interventions was introduced and modeled to the students. On the sixth day intervention sessions began. Each morning, assessment probes for all three problem sets were administered to collect DCM data. Interventions alternated with one being conducted in the morning immediately following the assessment probes, and the other intervention being implemented in the afternoon. Intervention sessions were conducted for nine days.

Visual analysis of time-series graphs was utilized to compare the daily mean DCM across baseline and intervention phases for each problem set. During the first six intervention sessions, Problem Set C (TP) demonstrated an unstable but increasing trend in mean DCM while Problem Sets A (control) and B (CCC) demonstrated little change. During the final three days, Problem Sets A and B demonstrated an increasing trend in mean DCM while increases in Problem Set C appeared to decline.

Descriptive statistics were utilized to analyze and compare DCM mean scores of baseline data and DCM median scores of the final three intervention data points across sets. The difference in classroom mean between scores for Set C (M=13.5) were greater than both Set B (M=6.6) and Set A (M=5.3). Analysis of individual student DCM mean scores of baseline data and DCM median scores of the final three intervention data points indicated that 16 students (80%) demonstrated greatest gains with the TP intervention, two students demonstrated greatest gains with both the TP intervention and control, and two students demonstrated greatest gains with the CCC intervention.

Results of this study suggested that TP has a higher learning rate than CCC when instructional time was held constant at six minutes across the two class-wide interventions. However, variability in individual student gains indicated that TP was ineffective or less effective than CCC for some students.

Finally, McCallum and Schmitt (2011) revisited the TP intervention to evaluate the effectiveness on a student with an intellectual disability. TP interventions have been utilized to increase both word list reading fluency as well as math fact fluency, and this study sought to expand the evidence for populations which the intervention proved successful. The research question was: What is the effectiveness of a self-monitored TP intervention on the division facts fluency of an eighth-grade student with an intellectual disability?

The sample consisted of one 13 year old, eighth-grade female from a public middle school in the Northeastern United States. She received special education services as a student with an intellectual disability that was reported to have resulted from a cerebrovascular accident at birth. Within a self-contained life skills classroom, she received speech, occupational, and physical therapies. The most recent psycho-educational evaluation data revealed that she earned an FSIQ of 59 and an adaptive behavior composite of 70.

The researchers utilized a multiple-probes-across-tasks design. The independent variable was a TP intervention. The dependent variable was digits correct per two minutes (DC2M) measured on assessment probes. A two-digit answer received 0-2 points, depending on the placement of each digit.

Basic division facts two through nine were divided into three sets, A, B, and C, of 12 problems. Problems with a quotient of zero and one were excluded, as were inversion facts (e.g. 14÷2 or 14÷7, but not both). CDs were created for each set. On a CD, the 12 problems were read aloud with a two seconds delay between each problem and its answer. Each set was read four times, and for each reading the order of problems was randomized. The student listened to the CD while attempting to write the answer on a corresponding worksheet before it was provided. Assessment probes for each problem set were also created. Each probe included the 12 problems of that set in random order repeated four times for 48 problems.

A baseline phase began with assessment probes for all three problem sets being administered on four consecutive days. The intervention phase began the following week, and was three weeks in duration. Each week the TP intervention targeted a single set of problems for four consecutive days: Set A the first week, Set B the second week, and Set C the third week. An intervention session consisted of an assessment followed by the TP intervention, all specific to the targeted set for that week. Prior to beginning the intervention for the next set of problems, assessments for all three sets were administered. One and two weeks following the final intervention session, assessments for all three problem sets were administered as part of the maintenance phase.

Visual analysis of data graphed by session was utilized to compare the daily DC2M across baseline, intervention, and maintenance phases for each problem set. During the intervention phase, DC2M scores demonstrated an increasing trend for all three problem sets. Differences between the last baseline data point and the first assessment following an intervention session demonstrated increases from one problem set to the next. The difference in this performance measured 3, 9, and 20 DC2M for Sets A, B, and C, respectively. Maintenance phase data compared to the intervention phase demonstrated sustained DC2M performance.

The results of this study suggested that a TP intervention increased math fact fluency immediately after the introduction of the intervention and is sustained following the termination of the intervention. It was postulated that the increasing difference between the last baseline data point and the first assessment could be due to the student becoming more accustomed to the procedures and was able to better focus on the math facts as opposed to the TP process.

This section focused on six studies specifically evaluating a TP intervention including the efficiency and component effectiveness. It was demonstrated that the intervention was effective in a class-wide setting (McCallum, Skinner, Turner, & Saecker, 2006) as well as on students with intellectual disabilities (McCallum & Schmitt, 2011). It was also determined that a posttest, delay condition, and reward did not consistently improve effectiveness of the intervention (Bliss et al., 2010; Poncy, Jaspers, Hansmann, Bui, & Matthew, 2015; McCallum, Schmitt, Schneider, & Rezzetano, 2010). Finally, when compared with a CCC intervention, TP demonstrated greater efficiency for most students (Poncy, Skinner, & McCallum, 2012).

Math Fact Fluency Obstacles

The two studies (DeVisscher & Noel, 2014; Ramos-Christian, Schleser, & Varn, 2008) in this section explore the relationships between math fact fluency and student abilities. Both studies divided students into two groups based on specific characteristics, administered tests, and then utilized correlational analyses to determine significant differences between groups. Identifying the nature of math fact fluency and the difficulties students may face were the goals of these studies.

DeVisscher and Noel (2014) tested the general applicability of a new hypothesis regarding the interference caused by overlapping features of arithmetic facts. When children attempted to learn facts, they had to cope with tremendous overlap between previously memorized facts and the new ones. For example, 6x7=42 and 6x8=48 have a common factor as well as a common tens place in the product. A hypersensitivity-to-interference was thought to potentially cause difficulties in learning arithmetic facts. The research question was: Is there a relationship between hypersensitivity-to-interference and low arithmetic fluency in students?

The sample consisted of 46 fourth grade students, 22 female and 24 male, from three French-speaking elementary schools in Belgium. The students were selected from 101 children, based on scores from assessments from the Symbols subtest of the Wechsler Intelligence Scale for Children (Wechsler, 2005) that were utilized to assess arithmetic fluency and processing speed. Two groups were created: 23 students with low arithmetical fluency (AF) and 23 students with typical AF. Typical AF students were matched on classroom, gender, and age, and scored in the arithmetical fluency task at least one standard deviation above their low AF student peer.

The researchers utilized a quantitative correlational design. The independent variable was the level of AF each child was placed. The dependent variable was the sensitivity-to-proactive interference of children in the context of associative memory.

Utilizing a computer program, students were first presented three pictures of cartoon characters each paired with a picture of a place and directed to memorize the pairings (e.g., the learning phase). Students were then presented three pairings in succession and asked if each pairing was accurate (e.g., the verification phase). After the initial block (a learning phase and a verification phase), the computer indicated that the cartoons moved locations and the student was to forget the previous associations and memorize the new ones. Twenty blocks each consisting of three pairings followed by three verifications were conducted, approximately 15 minutes in duration. The 60 verification trials were considered either low interference for pictures displayed for the first time, or high interference for pictures displayed in a previous verification stage but with different pairings.

A repeated measures ANOVA was utilized to analyze the correlation between mean scores and standard deviations of low AF students and typical AF students for both low interference and high interference conditions. For the low interference condition, low AF students (M=95.29, SD=3.85) performed similarly to typical AF students (M=97.25, SD=4.19), $t(44)$=-1.69, p=.106. For the high interference condition, low AF students (M=83.33, SD=7.87) performed significantly lower than typical AF students (M=90.36, SD=7.89), $t(44)$=-3.027, p=.004.

The results demonstrated that low AF students were subject to a significantly higher sensitivity-to-interference than the typical AF students, and suggested a correlation between sensitivity-to-interference and a difficulty with arithmetic fluency. However, the performance of low AF students in the low interference condition indicates that they had typical associative memory.

Ramos-Christian, Schleser, and Varn (2008) similarly investigated the relationship between cognitive ability and math fluency with first and second grade students of varying cognitive developmental level. Fluency, a combination of accuracy and speed of response, and cognitive abilities are both important to solving mathematical problems. Understanding the relationship between these abilities was important to teaching effective arithmetic skills. The research hypotheses were: Concrete operational children and preoperational children will differ significantly on math fluency, Concrete operational children and preoperational children will differ significantly on speed, and There will be no significant difference between concrete operational and preoperational children's math performance rate of accuracy.

The sample consisted of 39 students, 17 first graders and 22 second graders, from a general classroom in an elementary school in Illinois. Twenty-two were female and 17 were male. Fifty-nine percent were Caucasian, 39% were African-American, and 3% were of other ethnicities.

The researchers utilized a quantitative correlational design. The independent variable was the cognitive developmental level of the students, assessed as either preoperational or concrete operational by administering two conservation tasks that were utilized to evaluate whether a student could conserve one aspect of a quantity while another aspect changed. The three dependent variables were fluency, percentage correct, and number attempted. The Math Fluency subtest of the Woodcock Johnson Tests of Achievement, 3rd Edition (WJ-III; Woodcock, McGrew, & Mather, 2001) was utilized to assess the dependent variables.

Researcher-created conservation tasks, utilized to evaluate whether a child can conserve one aspect of quantity while another aspect changes, were administered first to each student to determine his or her cognitive developmental level. The Conservation of Number task involved three trials using six black and six red checkers. Trial One established that there were equal amounts of each color by placing both the black and red checkers in two parallel rows of equal sizes. Students were asked, “Are there as many red checkers as black checkers or is there more of one kind?” Trial Two involved elongating only the red row and asking the same question, as well as the question, “How did you know?” Trial Three involved creating a circle with the red checkers and asking the same two questions.

The Conservation of Substance task involved two trials using two balls of equal amounts of Play-Doh. For Trial One, students were asked, “Is there as much Play-Doh in both shapes, or is there more in one than the other?” Trial One established that there were equal amounts of Play-Doh, and if a student believed one shape contained more he or she was directed to “fix it.” Trial Two involved the researcher rolling one ball into a tubular shape, placing it vertically next to the other ball, and asking the same question as in Trial One. The student was also asked, “How did you know?” Students were scored one point for each correct response on both tasks and total scores ranged from 0 to 6. Total scores of 0 or 1 indicated that a student failed both tasks and was functioning at the preoperational stage of cognitive development. Total scores of 5 or 6 indicated that a student successfully completed both tasks and was functioning at the concrete operational stage. Of the 68 students screened, only those with a score of 1 or 6 were selected for the study.

Based on the conservation tasks scores, 19 of the students were placed into the preoperational group and 20 were placed into the concrete operational group. The 39 students were then assessed utilizing the WJ-III to measure fluency ability. The Math Fluency subtest consisted of simple one-digit addition, subtraction, and multiplication problems which students were to answer as quickly as possible in three minutes. Accuracy was determined by calculating percentage correct, speed was determined by the number of actual problems answered within the time limit, and fluency was determined by combining the accuracy and speed scores.

One-way analyses of variance (ANOVA) were conducted on the WJ-III raw scores to measure the significant differences between the cognitive developmental levels for each of the three dependent variables. The fluency mean scores for the concrete operational group (M=66.25, SD=18.15) were significantly higher than the preoperational group (M=42.37, SD=23.31), $F(1, 38)=12.82$, $p<.05$. The speed mean scores for the concrete operational group (M=34.40, SD=8.75) were significantly higher than the preoperational group (M=22.42, SD=11.39), $F(1, 38)=13.64$, $p<.05$. The accuracy mean scores for the concrete operational group (M=91.75, SD=11.32) demonstrated no significant difference than the preoperational group (M=84.50, SD=15.77), $F(1, 38)=2.46$, $p=.125$.

The results supported all three hypotheses: concrete operational students had greater math fluency and speed than preoperational students while accuracy rates between the two groups were similar. Revealed differences between the two cognitive developmental groups could be important to teachers who could reduce the differences through appropriate intervention techniques or by creating an environment with less time restrictions.

The studies in this section analyzed relationships between math fluency ability and cognitive abilities. Both students with sensitivity-to-interference (DeVisscher & Noel, 2014) as well as in the preoperational development stage (Ramos-Christian, Schleser, & Varn, 2008) were found to have lower math fluency than their peers.

Conclusion

The literature review consisted of eight studies that investigated TP intervention and math fact fluency. The first six studies (Bliss et al., 2010; McCallum & Schmitt, 2011; McCallum, Schmitt, Schneider, & Rezzetano, 2010; McCallum, Skinner, Turner, & Saecker, 2006; Poncy, Jaspers, Hansmann, Bui, & Matthew, 2015; Poncy, Skinner, & McCallum, 2012) evaluated TP intervention components as well as its effectiveness and efficiency. The intervention was determined to be effective at increasing math fluency in a class-wide setting (McCallum, Skinner, Turner, & Saecker, 2006) as well as for students with intellectual disabilities (McCallum & Schmitt, 2011). Furthermore, Bliss et al. (2010) demonstrated a daily posttest did not consistently increase math fluency, results from Poncy, Jaspers, Hansmann, Bui, and Matthew (2015) suggested a no delay condition achieved similar gains while utilizing one third less instruction time, and McCallum, Schmitt, Schneider, and Rezzetano (2010) indicated there was no significant difference in gains when a reward was introduced. The sixth study compared TP and CCC interventions (Poncy, Skinner, & McCallum, 2012) and demonstrated that TP had a higher learning rate with the majority of students tested.

Two correlational studies (DeVisscher & Noel, 2014; Ramos-Christian, Schleser, & Varn, 2008) regarding relationships between student abilities and math fact fluency were also reviewed. DeVisscher and Noel (2014) demonstrated that students with low arithmetic fluency were likely to have a sensitivity-to-interference. Results of Ramos-Christian, Schleser, and Varn (2014) suggested that while both concrete operational and preoperational students complete math facts with similar accuracy, students in the former group had greater fluency and speed than the latter.

CHAPTER THREE: METHODOLOGY

The purpose of this action research study was to increase multiplication fact fluency for a small class of fourth grade students by implementing an efficient intervention model. The ability to recall math facts quickly and accurately has been determined to be a significant contributing factor in the development of advanced cognitive strategies and solving complex arithmetic problems as students matriculate into higher grade levels (Carr & Alexeev, 2011; Vasilyeva, Laski, & Shen, 2015). The research question was: What are the effects of a Taped Problems (TP) intervention on multiplication fact fluency of fourth grade Title I math students? The research design was a quantitative, quasiexperimental, one-group pretest-posttest design. The independent variable was a TP intervention. Students listened to a series of multiplication fact problems (see Appendix A) and answers read on an audio recording. Students concurrently read a printed copy of the problems without answers (see Appendix B) and were instructed to "beat the recording" by writing the correct answer to each problem before it was spoken on the recording. The dependent variable was digits correct per minute (DCM) measured on researcher modified assessment probes (see Appendix C), consisting of 48 multiplication problems, administered at various intervals during the study. Based on Deno and Merkin's (1977) scoring procedure, a two-digit answer could receive 0-2 points, depending on the placement of each digit. For example, with the problem 3x5 =__, an answer of 45 would receive 2 points because both digits were in the correct place. An answer of 15, or 42 would receive 1 point. An answer of 10 or 54 would receive 0 points.

Description of Site and Sample

The study was conducted in an urban Muslim school located in the Midwest. There were 762 students enrolled in K5 through twelfth grade. The student population was 43% boys and

57% girls. Ethnicity demographics consisted of 53.5% Caucasian, 31.1% Asian, 14.7% African American, and 0.7% were two or more ethnicities. The sample consisted of five fourth grade students from a Title I math classroom during the fourth quarter of the school year. Student ages ranged from nine to eleven years, with a mean age of 9.8 years. Four were male and one was female. Two students were African-American and three were Asian. Three students spoke English as a second language. All students were identified as requiring Title I math services three times per week based on standardized tests scores and informal assessments administered during the first quarter of fourth grade. The mean mathematics RIT score for these students on the Fall 2015-16 Measures of Academic Progress test (Northwest Evaluation Association, 2012) was 179.6 compared to the Norm Grade Level mean RIT of 202. Baseline data from this study placed four students in the frustration level and one in the instructional level regarding multiplication math fluency (Deno & Merkin, 1977)

Description of Procedure

Basic multiplication facts 2-9, excluding multiples of 0 and 1, were divided into three sets, A, B, and C, of 12 problems each (see Appendix A). Audio recordings were created for each set using a voice memo app on the researcher's smartphone. On each recording, the 12 problems and their answers were read aloud in random order four times for 48 problems. All 12 problems were read once before being repeated. Problems were numbered 1-48 and the number of the problem was stated immediately preceding the reading of the problem. Four recordings were created for each set of problems, with no two recordings listing the problems in the same order. Intervention worksheets (see Appendix B) were created to match each recording, with the first 24 problems printed on one sheet, and the last 24 problems printed on a second sheet.

During a TP intervention session, students were provided an intervention worksheet packet and instructed to listen to the recording. Each recording began with the following instructions, "I will be reading multiplication problems and answers to you. Follow along on your sheet and try to write down the answer before I say it. If you write the wrong answer, cross it out and quickly write the correct answer next to it. If an answer is given before you write something, write the correct answer. Also, do not work ahead. Only write the answer for a problem that I am currently reading. That way, if you make a mistake you will be able to correct it immediately. Ok, pick up your pencils and let's begin." The researcher observed the classroom and monitored the students while the recording played. When the recording ended the intervention worksheets were collected.

TP intervention sessions were approximately five to six minutes in duration. The four intervention recordings of a single set were implemented in a single week on four consecutive school days, Monday through Thursday. During the intervention phase, Problem Set A was targeted the first week, Problem Set B was targeted the second week, and Problem Set C was targeted the third week.

Description of Data Collection and Assessment Instruments

Researcher modified assessment probes were created for each specific Problem Set (A, B, and C). An assessment probe (see Appendix C) contained 48 problems on one page, with each of the 12 problems of that set repeated four times. The problems were randomly sequenced, with each problem appearing once before any problem was repeated. No two probes listed the problems in the same order.

Assessment probes were administered at various intervals during the study to serve three purposes: baseline data, intervention data, and maintenance data. The baseline phase, utilized to establish baseline DCM data, involved the administration of assessment probes on three days over the course of a week, prior to the initial TP intervention. Each day probes for all three Problem Sets were administered in random order. Baseline assessments for Problem Sets B and C were also administered on the first day of TP intervention for Problem Set B, and another baseline assessment for Problem Set C was administered on the first day of TP intervention for Problem Set C. This was to confirm that the baseline for Problem Set B remained consistent after a week of TP intervention for Problem Set A and the baseline for Problem Set C remained consistent after two weeks of TP intervention for both Problem Sets A and B. Intervention DCM data were collected from assessment probes administered at least one day following each of a Problem Set's four intervention sessions. The probes were utilized to measure the effects of the previous day's TP intervention. The first three intervention assessment probes for a Problem Set were administered immediately preceding the following day's TP intervention session. The fourth intervention assessment probe was administered on the following Monday, immediately preceding the TP intervention session for the next Problem Set. Maintenance DCM data, utilized to indicate maintenance of treatment effect for each Problem Set, consisted of an assessment probe administered once a week for three weeks after the fourth intervention assessment probe was administered.

Administration of each assessment type, baseline, intervention, and maintenance, followed the same steps, only differing in the number of assessments (see Table 1 for a detailed schedule). The researcher distributed one, two, or three probes to the students, instructed the students to write their name at the top of the first page, then flip their packet over. The following directions were then read aloud, "We are going to take a one-minute math test. I want you to write your answers to some multiplication problems. Look at each problem carefully before you answer it. When I say ‘Go’ write your answer to the first problem (point to first problem) and work *across* the page without skipping any. Then go to the next row. Try to answer each problem. If you come to one you really don’t know, put an X through it and go to the next one. When you hear the bell, stop answering questions. Are there any questions? Go.” When one minute was complete the students were instructed stop. If additional assessments followed, the students were instructed to turn to the next page and wait for the researcher to say “Go” again. Once complete, the assessment(s) were collected and no performance feedback was provided. Assessment sessions were approximately two to four minutes in duration.

Table 1

Schedule of Assessment and TP Intervention Administration

Week	Day	Assessment Type and Set	TP Intervention Set
1	1	Baseline A/B/C	---
	2	Baseline A/B/C	---
	3	Baseline A/B/C	---
2	4	---	A
	5	Intervention A	A
	6	Intervention A	A
	7	Intervention A	A
3	8	Intervention A / Baseline B / Baseline C	B
	9	Intervention B	B
	10	Intervention B	B
	11	Intervention B	B
4	12	Intervention B / Baseline C	C
	13	Intervention C	C
	14	Intervention C	C
	15	Intervention C	C
5	16	Intervention C	---
	17	Maintenance A/B/C	---
6	18	Maintenance A/B/C	---
7	19	Maintenance A/B/C	---

Data Analysis Plan

DCM scores for each student on all assessments were entered onto an Excel spreadsheet. The class's mean DCM score for each assessment were calculated and plotted onto line graphs for visual analysis of trends. Within each Problem Set, class mean scores for baseline and maintenance assessments were analyzed using a two-tailed dependent *t*-test to determine if there were significant differences in DCM gains.

Additionally, individual student mean DCM scores for each assessment (baseline, intervention, and maintenance) within each problem set were analyzed utilizing Deno and Mirkin's (1977) criteria for frustration, instructional, and mastery levels. For grades four and higher, DCM scores of 0-19 were considered frustration, DCM scores of 20-39 were considered instructional, and DCM scores of 40 or more were considered at the mastery level.

Summary of Methodology

The purpose of this action research study was to determine if a TP intervention will increase multiplication fact fluency for five fourth grade Title I math students who were not proficient. Students were initially assessed to establish baseline data during the course of a week. For the next three weeks, the intervention phase began, with each week targeting a single Problem Set. Intervention assessments were administered at least one day after each TP intervention session, and maintenance assessments were administered after the four TP intervention sessions of a set of problems had been terminated. To measure change in the DCM for each Problem Set, the class mean for each intervention assessment was visually analyzed for trends, and a two-tailed dependent *t*-test compared the baseline class mean and the maintenance class mean. Individual student mean DCM scores for each assessment (baseline, intervention, and maintenance) across all three sets were analyzed utilizing Deno and Mirkin's (1977) criteria for frustration, instructional, and mastery levels.

CHAPTER FOUR: RESULTS

The purpose of this action research study was to increase multiplication fact fluency for a small class of fourth grade students by implementing an efficient intervention model. The ability to recall math facts quickly and accurately has been determined to be a significant contributing factor in the development of advanced cognitive strategies and solving complex arithmetic problems as students matriculate into higher grade levels (Carr & Alexeev, 2011; Vasilyeva, Laski, & Shen, 2015). The research question was: What are the effects of a Taped Problems (TP) intervention on multiplication fact fluency of fourth grade Title I math students? The research design was a quantitative, quasiexperimental, one-group pretest-posttest design. The independent variable was a TP intervention. Students listened to a series of multiplication fact problems (see Appendix A) and answers read on an audio recording. Students concurrently read a printed copy of the problems without answers (see Appendix B) and were instructed to "beat the recording" by writing the correct answer to each problem before it was spoken on the recording. The dependent variable was digits correct per minute (DCM) measured on researcher modified assessment probes (see Appendix C), consisting of 48 multiplication problems, administered at various intervals during the study. Based on Deno and Merkin's (1977) scoring procedure, a two-digit answer could receive 0-2 points, depending on the placement of each digit. For example, with the problem 3x5 =__, an answer of 45 would receive 2 points because both digits were in the correct place. An answer of 15, or 42 would receive 1 point. An answer of 10 or 54 would receive 0 points.

The first section presented and summarized the DCM data from class-wide and individual student assessment scores. The second section discussed how the data and resulting statistical analyses answered the research question. The final section summarized the results of the study.

Presentation and Summary of Data

Class-wide DCM Scores

Daily individual and class-wide mean DCM scores were presented in Tables 2, 3, and 4 for Problem Sets A, B, and C, respectively. Figures 1, 2, and 3 display line graphs of the daily class-wide mean DCM scores for each problem set. Visual analysis indicated an increasing trend in DCM scores within the baseline phase for the initial three assessment probes across problem sets. The additional baseline assessment probes for Problem Set B on Day 8 (see Figure 2) and Problem Set C on Days 8 and 12 (see Figure 3) demonstrated consistent baseline DCM scores while TP intervention of preceding problem sets were administered.

Visual analysis indicated an immediate mean DCM increase following the first day of the intervention phase across problem sets. Compared to the final baseline assessment probe, Problem Set A increased 4.6 DCM, Problem Set B increased 6.2 DCM, and Problem Set C increased 7.6 DCM. Within the intervention phase, an increasing trend can be observed across all problem sets with the exception of the final intervention assessment probe for Problem Set B.

Finally, visual analysis indicated a decrease in mean DCM scores upon the administration of the maintenance phase for Problem Sets A and C. Mean DCM scores for Problem Set B did not demonstrate an increasing or decreasing trend for the maintenance phase.

Table 2

Comparison of Individual and Class-wide Mean DCM scores – Problem Set A

	Baseline				Intervention					Maintenance		
Student	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9-16	Day 17	Day 18	Day 19
A	9	22	15	X	27	38	35	49	X	28	25	27
M	0	2	3	X	8	9	9	7	X	4	1	6
R	5	9	3	X	14	20	27	28	X	5	11	19
S	19	25	25	X	25	39	25	30	X	19	21	21
Z	9	17	17	X	20	21	27	18	X	13	9	17
Mean	8.4	15	12.6	X	18.8	25.4	24.6	26.4	X	13.8	13.4	18

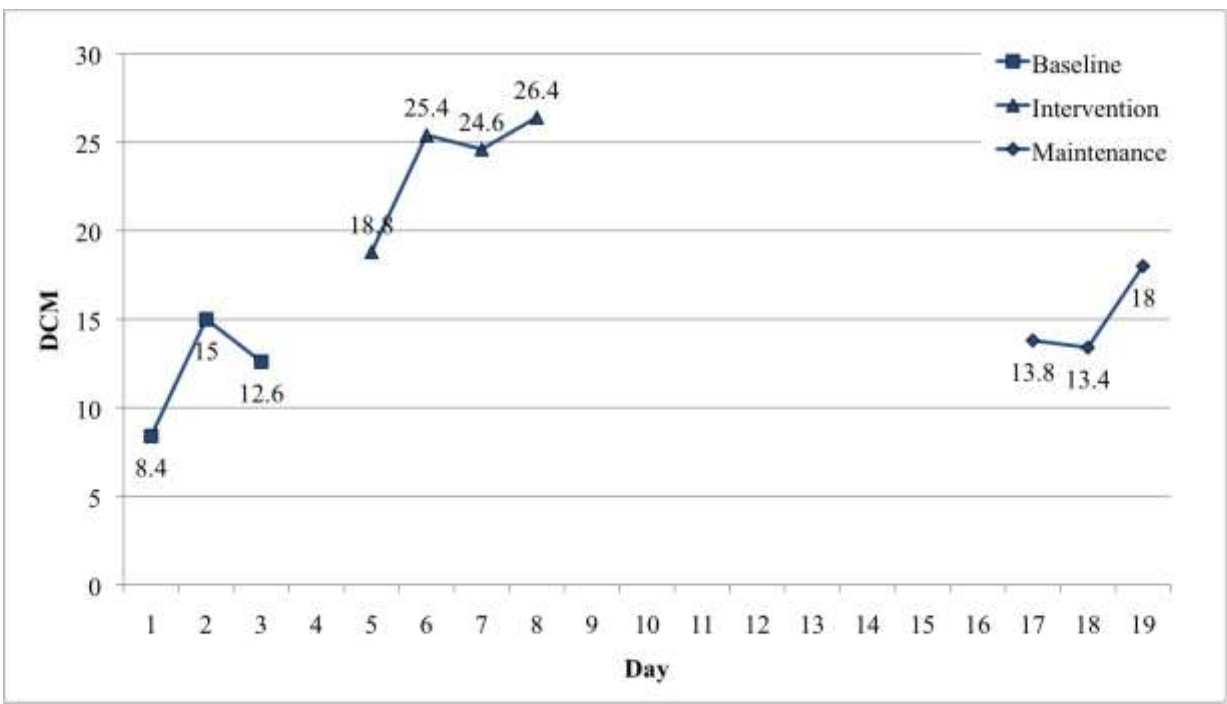

Figure 1

Daily Class-wide Mean DCM Scores – Problem Set A

Table 3

Comparison of Individual and Class-wide Mean DCM scores – Problem Set B

	Base line					Inter venti on					Mai nten ance		
Student	Day 1	Day 2	Day 3	Day 4-7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13-16	Day 17	Day 18	Day 19
A	9	17	19	X	15	24	23	26	21	X	37	31	32
M	5	5	4	X	7	7	7	9	4	X	4	8	2
R	7	8	16	X	11	15	13	17	7	X	8	11	8
S	14	20	23	X	16	29	32	29	35	X	27	29	21
Z	10	9	12	X	5	10	absent	13	9	X	15	11	15
Mean	9	11.8	14.8	X	10.8	17	18.75	18.8	15.2	X	18.2	18	15.6

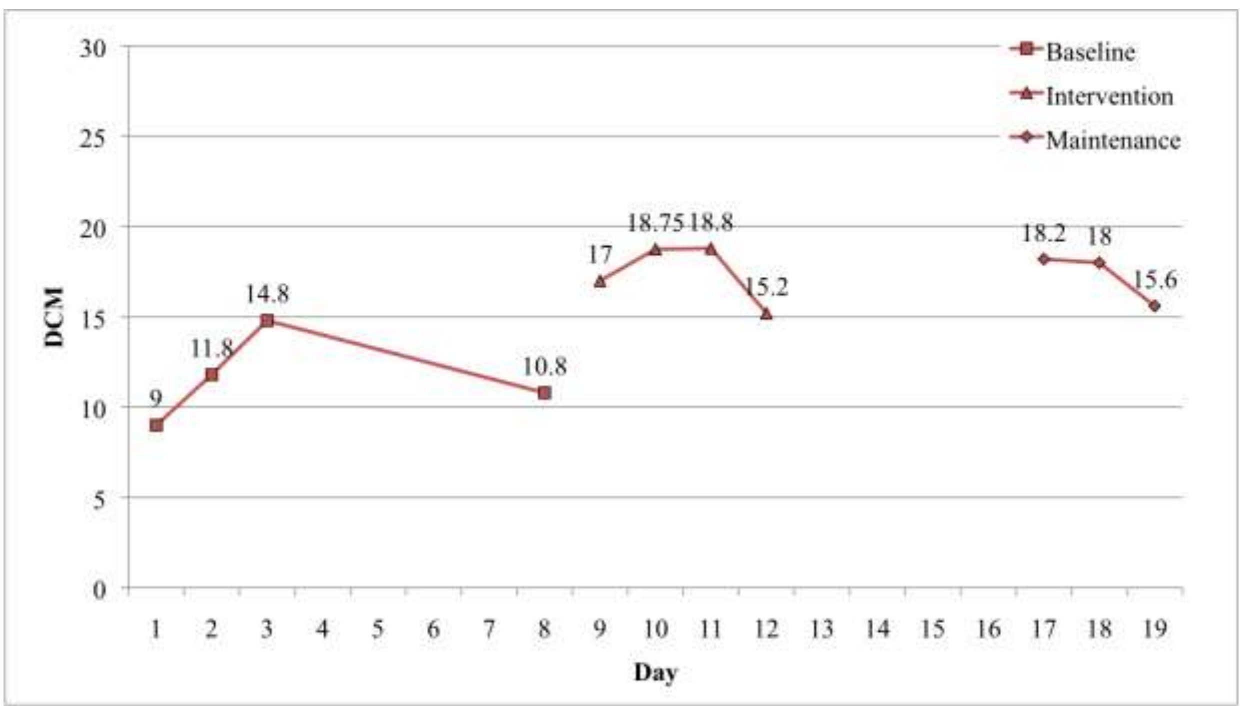

Figure 2

Daily Class-wide Mean DCM Scores – Problem Set B

Table 4

Comparison of Individual and Class-wide Mean DCM scores – Problem Set C

Student	Baseline Day 1	Day 2	Day 3	Day 4-7	Day 8	Day 9-11	Day 12	Intervention Day 13	Day 14	Day 15	Day 16	Maintenance Day 17	Day 18	Day 19
A	16	24	26	X	22	X	24	42	48	44	49	42	52	43
M	1	3	3	X	4	X	3	3	1	2	2	4	4	6
R	12	9	9	X	8	X	8	5	17	17	22	13	23	16
S	15	18	24	X	22	X	13	25	38	37	39	26	35	30
Z	8	8	14	X	6	X	7	18	23	25	24	21	9	22
Mean	10.4	12.4	15.2	X	12.4	X	11	18.6	25.4	25	27.2	21.2	24.6	23.4

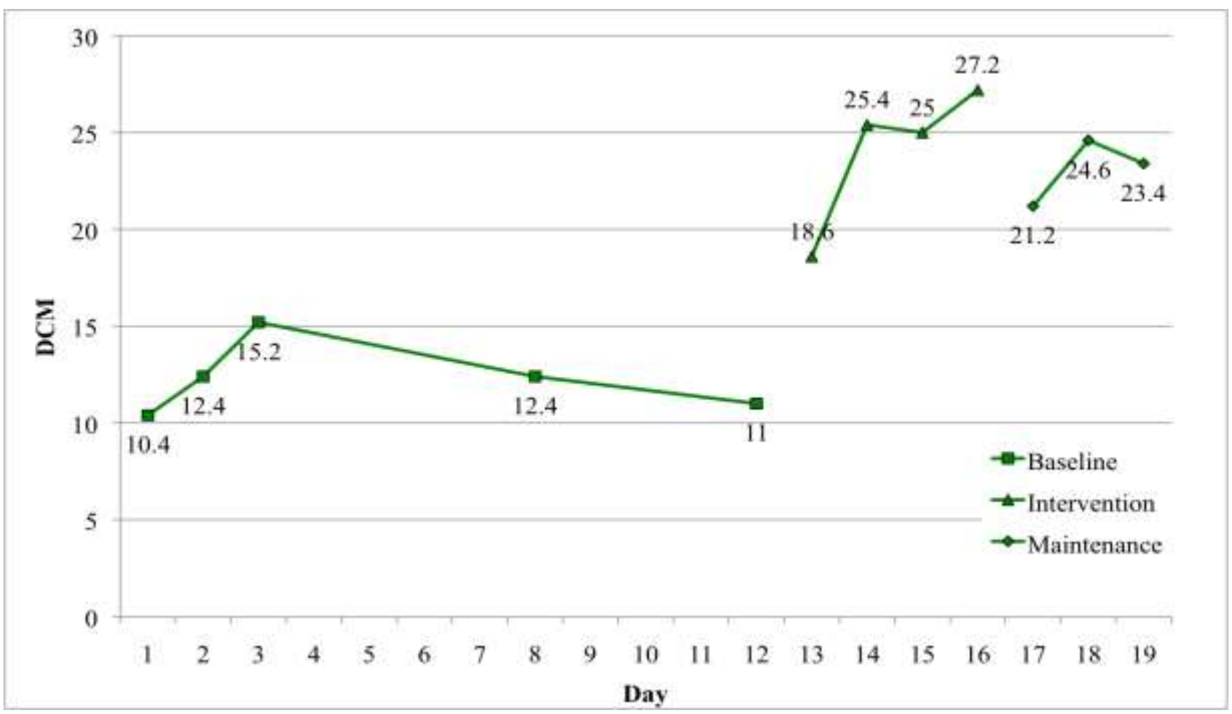

Figure 3

Daily Class-wide Mean DCM Scores – Problem Set C

To compare means, the first three baseline mean DCM scores were averaged for each problem set, as were the three maintenance mean DCM scores (see Table 5). For Problem Set A, results of a two-tailed dependent *t*-test indicated that for Problem Set A there was no significant difference between the mean baseline score (*M*=12, *SD*=8.57) and the mean maintenance score (*M*=15.07, *SD*=8.76), *t*(14)=-1.60, *p*=0.13. Regarding Problem Set B, results of a two-tailed dependent *t*-test indicated a significant difference between the mean baseline score (*M*=11.87, *SD*=6.00), *t*(14)=-2.37, *p*<.05. Regarding Problem Set C, results of a two-tailed dependent *t*-test indicated a significant difference between the mean baseline score (*M*=12.67, *SD*=7.91) and the mean maintenance score (*M*=23.07, *SD*=15.04), *t*(14)=-4.60, *p*<.05.

Table 5

Comparison of Class-wide Mean DCM Scores between Baseline and Maintenance Phases

Set	Baseline	Maintenance	DCM Increase
A	12	15.07	3.07
B	11.87	17.27	5.4
C	12.67	23.07	10.4

Individual Student DCM Scores

Using Deno and Mirkin's (1977) criteria for frustration, instructional, and mastery level, each student's individual mean DCM score within the baseline, TP intervention, and maintenance phase was categorized for each problem set. For grades four and higher, DCM scores of 0-19 were considered frustration, DCM scores of 20-39 were considered instructional, and DCM scores of 40 or more were considered at the mastery level. On Problem Set A (see Table 6) three students increased from frustrational level to instructional level during the intervention phase, two of which returned to frustrational level during the maintenance phase. Throughout the study Student M remained in the frustrational level and Student S remained in the instructional level. DCM changes from baseline phase to intervention phase ranged from increases of 21.92 to 6.48. DCM changes from baseline phase to maintenance phase ranged from an increase of 11.34 to a decrease of 2.67.

Table 6

Individual Student Mean DCM and Corresponding Instructional Level (IL) – Problem Set A

	Baseline		Intervention		Maintenance	
Student	DCM	IL	DCM	IL	DCM	IL
A	15.33	F	37.25	I	26.67	I
M	1.67	F	8.25	F	3.67	F
R	5.67	F	22.25	I	11.67	F
S	23	I	29.75	I	20.33	I
Z	14.33	F	21.5	I	13	F

Note. F = Frustrational; I = Instructional; M = Mastery

On Problem Set B (see Table 7) two students increased from frustrational to instructional level during the interventional phase, and remained at that level during the maintenance phase. Three students remained in the frustrational level throughout the study. DCM changes from baseline phase to intervention phase ranged from increases of 12.25 to 0.34. DCM changes from baseline phase to maintenance phase ranged from an increase of 18.33 to a decrease of 1.33.

Table 7

Individual Student Mean DCM and Corresponding Instructional Level (IL) – Problem Set B

	Baseline		Intervention		Maintenance	
Student	DCM	IL	DCM	IL	DCM	IL
A	15	F	23.5	I	33.33	I
M	4.67	F	6.75	F	4.67	F
R	10.33	F	13	F	9	F
S	19	F	31.25	I	25.67	I
Z	10.33	F	10.67	F	13.67	F

Note. F = Frustrational; I = Instructional; M = Mastery

On Problem Set C (see Table 8) one student increased from instructional level to mastery level during the interventional phase, and remained at that level during the maintenance phase demonstrating a gain of 23.67 mean DCM. Two students increased from frustrational level to instructional level during the interventional phase, one of which returned to frustrational level during the maintenance phase. Students M and R remained in the frustrational level throughout the study, although Student R did have an increase of 7.33 mean DCM from the baseline phase to the maintenance phase. DCM changes from baseline phase to intervention phase ranged from an increase of 23.75 to a decrease of 0.33. DCM changes from baseline phase to maintenance phase ranged from increases of 23.67 to 2.34.

Table 8

Individual Student Mean DCM and Corresponding Instructional Level (IL) – Problem Set C

	Baseline		Intervention		Maintenance	
Student	DCM	IL	DCM	IL	DCM	IL
A	22	I	45.75	M	45.67	M
M	2.33	F	2	F	4.67	F
R	10	F	15.25	F	17.33	F
S	19	F	34.75	I	30.33	I
Z	10	F	22.5	I	17.33	F

Note. F = Frustrational; I = Instructional; M = Mastery

Findings Related to Research Question

The research question was: What are the effects of a Taped Problems (TP) intervention on multiplication fact fluency of fourth grade Title I math students? The mean DCM score increased from the baseline phase to the maintenance phase by 3.07, 5.4, and 10.4 for Problem Sets A, B, and C, respectively. The mean increase for Problem Sets B and C were significant. Further evidence of an increase in DCM was demonstrated by analyzing individual student mean scores for each phase using Deno and Mirkin’s (1977) criteria for frustration, instructional, and mastery levels. For Problem Set A, three students increased from the frustrational level to the instructional level. For Problem Set B, two students increased from the frustrational level to the instructional level. For Problem Set C, one student increased from the instructional level to the mastery level, and two students increased from the frustrational level to the instructional level. Not all students demonstrated increases in mean DCM scores.

Summary Conclusion

To test the effect TP intervention had on student multiplication fact fluency, mean DCM scores on baseline assessment probes were compared to mean DCM scores on maintenance assessment probes with a two-tailed dependent *t*-test. For two of the three problem sets, the maintenance mean DCM scores increased significantly over the baseline mean DCM scores. Furthermore, analysis of individual student mean DCM scores indicated an increase from either frustrational level to instructional level or instructional level to mastery level (Deno & Mirkin, 1977). The data moderately supported the hypothesis that TP intervention affected student multiplication fact fluency.

CHAPTER FIVE: CONCLUSIONS AND DISCUSSION

The purpose of this action research study was to increase multiplication fact fluency for a small class of fourth grade students by implementing an efficient intervention model. The ability to recall math facts quickly and accurately has been determined to be a significant contributing factor in the development of advanced cognitive strategies and solving complex arithmetic problems as students matriculate into higher grade levels (Carr & Alexeev, 2011; Vasilyeva, Laski, & Shen, 2015). The research question was: What are the effects of a Taped Problems (TP) intervention on multiplication fact fluency of fourth grade Title I math students? The research design was a quantitative, quasiexperimental, one-group pretest-posttest design. The independent variable was a TP intervention. Students listened to a series of multiplication fact problems (see Appendix A) and answers read on an audio recording. Students concurrently read a printed copy of the problems without answers (see Appendix B) and were instructed to "beat the recording" by writing the correct answer to each problem before it was spoken on the recording. The dependent variable was digits correct per minute (DCM) measured on researcher modified assessment probes (see Appendix C), consisting of 48 multiplication problems, administered at various intervals during the study. Based on Deno and Merkin's (1977) scoring procedure, a two-digit answer could receive 0-2 points, depending on the placement of each digit. For example, with the problem 3x5 =__, an answer of 45 would receive 2 points because both digits were in the correct place. An answer of 15, or 42 would receive 1 point. An answer of 10 or 54 would receive 0 points.

The results of a two-tailed dependent *t*-test indicated that for two of the three problem sets, the maintenance mean DCM scores increased significantly from the baseline mean DCM scores. Analysis of individual student mean DCM scores indicated multiple student increases from either frustrational level to instructional level or instructional level to mastery level (Deno & Mirkin, 1977).

Explanation for the Results

Visual analysis of the line graphs (see Figures 1, 2, and 3) indicated an initial mean DCM increase during the baseline phase and was potentially a result of students becoming accustomed to the assessment probes and process. Additional baseline scores for Problem Sets B and C remained consistent while the TP intervention phase began for Problem Set A, which suggested TP intervention for one set did not affect DCM scores for the other sets. Immediate mean DCM gains for each problem set after the introduction of the initial TP intervention for each problem set indicated the prompt impact of the intervention. The decline in mean DCM during the maintenance phase for Problem Sets A and C suggested weak retention of the multiplication facts learned during the intervention phase, primarily for Set A. Mean DCM scores during the maintenance phase of Problem Set C, however, remained notably higher than the baseline phase, indicating stronger retention than Sets A and B.

The significant increase of class-wide mean DCM scores from the baseline phase to the maintenance phase of Problem Sets B and C suggested that multiplication fact fluency increased due to the TP intervention. The mean DCM score for Problem Set A increased as well, but was not a significant difference. This less pronounced increase could have been a result of the larger span of time between the intervention and maintenance phases for Problem Set A when compared to Problem Sets B and C. The span of time decreased with each problem set: nine days for Problem Set A, five days for Problem Set B, and one day for Problem Set C. The decrease in mean DCM scores (see Table 5) as time increased suggested that a longer TP intervention phase might support stronger multiplication fact retention.

Individual student results (see Tables 6, 7, and 8) demonstrated that 53% of the students increased from one instructional level to the next (60% for Problem Sets A and C, and 40% for Problem Set B). These findings moderately supported McCallum, Skinner, Turner and Saecker (2006) who found 67% of the students made enough DCM gains to move into the next instructional level. However, only Student M, whose DCM scores were consistently the lowest of the sample group, failed to increase instructional level for all three problem sets. This suggested that either TP intervention might not be effective for a student whose baseline DCM scores are five or less, or TP intervention did not address the student's unique needs.

Connections Between the Literature Review and the Results

The effectiveness of a TP intervention on samples similar to those in this action research study was supported by two previous studies (McCallum & Schmitt, 2011; McCallum, Skinner, Turner, & Saecker, 2006). The TP intervention for this action research study was administered to the entire sample of five students as a group. McCallum, Skinner, Turner, and Saecker (2006) demonstrated a TP intervention was effective at increasing math fact fluency when administered to both individual students as well as class-wide. Additionally, McCallum and Schmitt (2011) determined a TP intervention was also effective with a sample consisting of a student with an intellectual disability. The students in this action research study had not been diagnosed as such, but received additional instruction from Title I based on low standardized test scores and classroom performance.

The results of this action research study regarding a TP intervention that increased fact fluency efficiently were supported by three previous studies (Bliss et al., 2010; McCallum, Schmitt, Schneider, Rezzetano, & Skinner, 2010; Poncy, Jaspers, Hansmann, Bui, & Matthew, 2015). In this action research, the time delay and additional daily assessment utilized in the original TP class-wide study (McCallum, Skinner, Turner, & Saecker, 2006) were removed to decrease the amount of time necessary for daily administration of the intervention. Poncy, Jaspers, Hansmann, Bui, and Matthew (2015) demonstrated that including a time delay does not increase the effectiveness of the intervention on math fact fluency. Bliss et al. (2010) determined that while an additional daily assessment does provide students with more opportunities to respond, it did not significantly increase the majority of student DCM scores. Furthermore, McCallum, Schmitt, Schneider, Rezzetano, and Skinner (2010) demonstrated adding a group reward for increased DCM scores did not induce greater gains.

Poncy, Skinner, and McCallum (2012) compared a TP intervention with Cover, Copy, and Compare intervention on math fact fluency. After the first intervention session, the TP intervention resulted in greater DCM increase than the Cover, Copy, and Compare intervention. The immediate and continued DCM increases after TP intervention was supported by results in this action research study.

Two correlational studies (DeVisscher & Noël, 2014; Ramos-Christian, Schleser, & Varn, 2008) that measured relationships between student cognitive abilities and math fact fluency demonstrated possible support for this action research study. DeVisscher and Noël (2014) determined that learning new math facts might be difficult for students with sensitivity-to-interference due to memorized math facts that include the same digits. For example, a student who understands the math equation 4 + 5 = 9 might have difficulty memorizing 4 x 5 = 20. This may support why 47% of the students in this action research study did not make meaningful DCM gains due to previous math fact knowledge. Conversely, student DCM scores in this study increased as Problem Sets B and C were introduced despite having been subjected to intervention of Problem Set A, which contained facts with the same digits. If the students had a sensitivity-to-interference one would assume the highest DCM increases would result from the first problem set, and then decrease with each newly introduced problem set. Ramos-Christian, Schleser, and Varn (2008) determined that concrete operational first and second grade students were more fluent with math facts than preoperational students. The students in this action research study were developmentally beyond the preoperational stage, but the study supported a relationship between cognitive abilities and math fluency that could affect mathematical performance.

Strengths and Limitations for the Results

In designing this action research study, the researcher knew time was limited in daily administration due to class schedules, as well as the entire data collection period due to an approaching summer break. Regardless of time limits, determining the most efficient teaching method was integral to a teacher's curriculum. A strength of the TP intervention was that it not only required minimal instruction time, but also had multiple supporting studies (Bliss et al., 2010; McCallum, Schmitt, Schneider, Rezzetano, & Skinner, 2010; Poncy, Jaspers, Hansmann, Bui, & Matthew, 2015) that suggested improvements to enable the intervention to be more efficient while remaining equally effective.

Another strength of this study was the immediate effectiveness of a TP intervention. It has been my experience that motivation often follows immediate positive feedback. For example, when I began rock climbing years ago my abilities and performance increased greatly within the first few weeks. Without that pride and excitement for improvement, the intrinsic motivation would have been absent, and it is doubtful that I would have persevered and continued to engage in the activity. The same was observed in multiple students after administration of an intervention assessment. The students were excited by the number of problems answered and proud to share news of their achievement with classmates. There was no doubt that this intrinsic motivation helped students focus and strive to achieve even greater DCM scores on subsequent assessments. The immediate effectiveness of a TP intervention also indicated that mastery level could be reached in fewer sessions than with alternative instructional methods allowing students to expeditiously move on to subsequent problem sets.

Although there were significant strengths, there were several limitations with this action research study as well. First, the sample size was extremely small. The class size of a Title I classroom were, by definition, small in number. The classroom for this study contained five students. Ideally, a large class would have been preferred as dependent *t*-test required sample sizes of 30 or more to confidently generalize results to the larger population. Unfortunately, this was not logistically possible for this study.

Another limitation was the time limit on data collection in conjunction with the design of the study. This action research attempted to replicate the multiple-probes-across-tasks design of McCallum, Skinner, Turner, and Saecker (2006) by administering the TP intervention to each problem set for a single week, but did not have similar prolonged maintenance results for Problem Sets A and B. Perhaps a larger percentage of students would have increased instructional levels posed by Deno and Mirkin (1977) if a single problem set had been assessed during the entire three weeks, or if each problem set were permitted additional intervention sessions to increase learning experiences and thus increase maintenance DCM scores.

One proposed reason for the effectiveness of the TP intervention was the students received immediate feedback while listening to the recording. If a student wrote the incorrect answer the recording provided the correct answer and allowed the student to adjust his or her mistake. In a small classroom, I was able to monitor all student progress during the intervention and remind students of the directions if any were observed working ahead of the recording.

However, if administered to a large class, it would be extremely difficult for a teacher to monitor all student progress. A student who ignored the recording and worked ahead may have written the incorrect answer but did not hear the correct answer.

Recommendations for Future Research

In this study, maintenance DCM scores decreased as time between the TP intervention and the maintenance assessment probes increased. The limitation of the four-day intervention session for each problem set may not have allowed sufficient practice for students to retain newly learned multiplication facts for an extended period of time. In studies conducted by McCallum, Schmitt, Schneider, Rezzetano, and Skinner (2010) and Poncy, Jaspers, Hansmann, Bui, and Matthew (2015) intervention sessions were two to three times as long as this study and resulted in greater sustained maintenance DCM scores. It is recommended that future research on TP intervention examine number of intervention sessions as related to sustained maintenance DCM scores.

One of the main advantages for utilizing a TP intervention was its efficiency; minimal instruction time was necessary for implementation in the classroom while retaining effectiveness. Training students to independently access the TP intervention for self-directed learning could maximize this efficiency and target specific problem sets for each student. Developing computer software could enhance student independence and ease of intervention implementation even further. Allowing peers to correct assessment probes and students to graph their own DCM progress are components that could provide additional learning opportunities as well as strengthen ownership and accountability over student growth while decreasing teacher workload. Further research examining the effects of these modifications to the TP intervention model is necessary to possibly increase efficiency.

It was observed during the intervention phase that a number of students would often review previous written answers to beat the recording as opposed to attempting to derive the answer from memory. This had not been discussed in previous TP studies, and it was unclear if this strategy would hinder for enhance fact memorization. Eliminating the choice to review previous answers by use of a computer program or other means (e.g. covering previously answered problems with blank paper or a possible folding system) would be another recommendation for future TP intervention research.

Finally, assessment scores of two students did not increase more than seven DCM for two or more of the problem sets in this study. Cover, Copy, Compare (CCC), an alternative intervention that was compared to TP intervention (Poncy, Skinner, & McCallum, 2012), was determined to be inferior in effectiveness for the majority of students when time was held constant. However, two of the twenty students in the sample achieved higher DCM scores with the CCC intervention. The effects of CCC intervention on multiplication fact fluency should be investigated with the two students who did not greatly increase DCM scores in this study.

Conclusion: Implications for Personal Practice

On a basic level, this action research study taught me a new research-based intervention that I can incorporate into the majority of my Title I Math classrooms, whether its assisting second and third graders master addition and subtraction or fourth and fifth graders master multiplication and division. Having this proven efficient and effective strategy to confidently help struggling students attain fluency while utilizing a minimal amount of instruction and class time will enable me to allocate energy and resources into other teaching endeavors. I also plan to share the results of this action research study to fellow teachers to promote use of the TP intervention in the classrooms. All students in the school may benefit from the findings, not only my Title I students. I hope to see the positive impact on our school's standardized test scores in mathematics this intervention may generate.

The process of action research, in a higher sense, has improved me as an overall teacher. Professional growth is integral, and I have always been one to continuously examine the methods and effects of my lessons plans. I do not shy away from identifying weaknesses to improve my pedagogic skills and styles. However, guesswork and Internet searches on www.Pinterest.com can only assist teachers so far. Action research has proven, without a doubt, the ease, tangible practicality, and significance of inquiry and applied research for guiding instruction and best practices. Through action research, I plan to become the teacher I have always strived to be, and the teacher my students need in their classroom.

References

Bliss, S. L., Skinner, C. H., McCallum, E., Saecker, L. B., Rowland-Bryant, E., & Brown, K. S. (2010). A comparison of taped problems with and without a brief post-treatment assessment on multiplication fluency. *Journal of Behavioral Education, 19*(2), 156-168.

Burns, M. K. (2005). Using incremental rehearsal to increase fluency of single-digit multiplication facts with children identified as learning disabled in mathematics computation. *Education and Treatment of Children, 28*(3), 237-249.

Carr, M., and Alexeev, N. (2011). Fluency, accuracy, and gender predict developmental trajectories of arithmetic strategies. *Journal of Educational Psychology, 103*(3), 617-631.

Deno, S. L., and Mirkin, P. K. (1977). *Data-based program modification: A manual.* Reston, VA: Council for Exceptional Children.

DeVisscher, A., & Noël, M. (2014). Arithmetic facts storage deficit: The hypersensitivity-to-interference in memory hypothesis. *Developmental Science, 17*(3), 434-442.

Freeman, T. J., & McLaughlin, T. F. (1984). Effects of a taped-words treatment procedure on learning disabled students' sight-word reading. *Learning Disability Quarterly, 7*(1), 49-54.

Lerner, J. (2003). *Learning disabilities: theories, diagnosis, and teaching strategies* (9th ed.). Boston, MA: Houghton Mifflin Company.

McCallum, E, & Schmitt, A. J. (2011). The taped problems intervention: Increasing the math fact fluency of a student with an intellectual disability. *International Journal of Special Education, 26*(3), 2011.

McCallum, E., Schmitt, A. J., Schneider, D. L., Rezzetano, K., & Skinner, C. H. (2010). Extending research on the taped-problems intervention: Do group rewards enhance math fact fluency development? *School Psychology Forum: Research in Practice, 4*(1), 44-61.

McCallum, E., Skinner, C. H., & Hutchins, H. (2004). The taped-problems intervention: Increasing division fact fluency using a low-tech self-managed time-delay intervention. *Journal of Applied School Psychology, 20*(2), 129-147.

McCallum, E., Skinner, C. H., Turner, H., and Saecker, L. (2006). The taped-problems intervention: Increasing multiplication fact fluency using a low-tech, classwide, time-delay intervention. *School Psychology Review, 35*(3), 419-434.

McDougall, D., and Brady, M. P. (1998). Initiating and fading self-management interventions to increase math fluency in general education classes. *Exceptional Children, 64*(2), 151-166.

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common core state standards for mathematics.* Washington, DC.

Northwest Evaluation Association. (2012). *Measures of Academic Progress.* Retrieved from http://www.nwea.org.

Poncy, B. C., Jaspers, K. E., Hansmann, P. R., Bui, L., & Matthew, W. B. (2015). A comparison of taped-problems interventions to increase math fact fluency: Does the length of time delay affect student learning rates? *Journal of Applied School Psychology, 31*(1), 63-82.

Poncy, B. C., Skinner, C. H., & McCallum, E. (2012). A comparison of class-wide taped problems and cover, copy, and compare for enhancing mathematics fluency. *Psychology in the Schools, 49*(8), 744-755.

Skinner, C. H., McLaughlin, T. F., & Logan, P. (1997). Cover, copy, and compare: A self-managed academic intervention effective across skills, students, and settings. *Journal of Behavioral Education, 7*(3), 295-306.

Vasilyeva, M., Laski, E. V., and Shen, C. (2015). Computational fluency and strategy choice predict individual and cross-national differences in complex arithmetic. *Developmental Psychology, 51*(10), 1489-1500.

Appendix A
Multiplication Sets

Set A	Set B	Set C
3 x 3	2 x 2	2 x 4
2 x 5	2 x 7	6 x 2
2 x 8	4 x 3	2 x 9
5 x 3	3 x 6	3 x 2
3 x 8	9 x 3	3 x 7
4 x 4	4 x 5	6 x 4
4 x 9	8 x 4	4 x 7
6 x 5	5 x 7	5 x 5
6 x 7	9 x 5	5 x 8
9 x 6	6 x 6	6 x 8
7 x 7	9 x 7	7 x 8
9 x 8	8 x 8	9 x 9

Appendix B
Intervention Worksheet

Name ________________

Intervention-A.2

1.	6 x 7 =	2.	5 x 3 =
3.	6 x 5 =	4.	2 x 8 =
5.	7 x 7 =	6.	2 x 5 =
7.	9 x 6 =	8.	3 x 3 =
9.	4 x 9 =	10.	4 x 4 =
11.	9 x 8 =	12.	3 x 8 =
13.	2 x 5 =	14.	7 x 7 =
15.	3 x 3 =	16.	9 x 6 =
17.	5 x 3 =	18.	6 x 7 =
19.	2 x 8 =	20.	6 x 5 =
21.	4 x 4 =	22.	4 x 9 =
23.	3 x 8 =	24.	9 x 8 =

Day 5

Intervention-A.2

25.	3 x 8 =	26.	7 x 7 =
27.	2 x 5 =	28.	9 x 6 =
29.	4 x 9 =	30.	2 x 8 =
31.	9 x 8 =	32.	4 x 4 =
33.	3 x 3 =	34.	6 x 7 =
35.	5 x 3 =	36.	6 x 5 =
37.	4 x 9 =	38.	3 x 8 =
39.	9 x 8 =	40.	2 x 5 =
41.	7 x 7 =	42.	5 x 3 =
43.	9 x 6 =	44.	3 x 3 =
45.	4 x 4 =	46.	2 x 8 =
47.	6 x 5 =	48.	6 x 7 =

Appendix C
Assessment Probe

Name ________________

Assessment-A.1

2 x 8 =	9 x 6 =	5 x 3 =	6 x 7 =
3 x 8 =	6 x 5 =	4 x 4 =	4 x 9 =
2 x 3 =	9 x 8 =	2 x 5 =	7 x 7 =
2 x 8 =	3 x 8 =	9 x 8 =	9 x 6 =
6 x 5 =	7 x 7 =	6 x 7 =	4 x 9 =
2 x 5 =	5 x 3 =	4 x 4 =	2 x 3 =
9 x 6 =	4 x 9 =	5 x 3 =	3 x 8 =
7 x 7 =	2 x 5 =	2 x 8 =	6 x 5 =
4 x 4 =	9 x 8 =	6 x 7 =	2 x 3=
4 x 9 =	2 x 5 =	4 x 4 =	9 x 6 =
7 x 7 =	2 x 3=	3 x 8 =	6 x 5 =
6 x 7 =	2 x 8 =	5 x 3 =	9 x 8 =