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Evidence-Based Practices for Tiered Math Interventions for Elementary Students

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Evidence-Based Practices for Tiered Math Interventions for Elementary Students

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Chapter I: Introduction

Being able to apply mathematics concepts are a necessity in almost any scenario that a person encounters. From cooking a meal to finding a time to meet with friends, math is needed to complete these tasks. Students that are at-risk learners are put at a great disadvantage compared to students that are not at-risk learners. At the elementary level, many students are yet to be identified for special education. This is due to students just beginning their education career and not having sufficient data to be identified as having a disability. These at risk students often find themselves receiving some form of an intervention at school. Students with math disabilities, in general, have deficits in executive functioning and problem-solving ability that contribute to this disadvantage. (Partanen et al., 2020) With this, it is paramount that educators are using evidence based tiered interventions for at-risk elementary math students to provide the best-case scenario for successful math outcomes.

Early math outcomes, like of students that are in elementary school, predict future performance in math. For example, Fuchs et al. (2019) state that first-grade achievement in arithmetic is a future predictor of performance in fifth-grade math performance and even high school algebra courses. This shows the importance of using evidence-based tiered interventions for at risk math students at the elementary level. The more successful students are at an early age with their math outcomes, the better chance they have at achieving higher math outcomes in future grade levels. According to the National Assessment of Education Progress (NAEP), 59% of fourth graders were not achieving at a proficient level in math in 2019. Further, the NAEP reports that in 2019, only 17% of fourth graders of students with disabilities achieved a proficient level in math. The percentages of students with disabilities achieving proficiently in math declines as students are in higher grade levels. Students with disabilities proficiency achievement in math decreases to 9% in eighth grade and 7% in 12^{th} grade. These statistics highlight the importance of needing to use evidence-based practices in math for students with disabilities at an early age due to early performance in math being a predictor for future outcomes. Additionally, once at risk students are identified as having a math disability, the statistics show they are likely not going to achieve proficient levels at their grade level. Using evidence-based practices in tiered interventions at the elementary level will create better opportunities for future success in higher grade levels.

Research Question

This starred paper will have one research question to guide the review of literature.

1. What instructional methods and strategies provide successful learning outcomes for elementary students receiving tiered interventions for math?

Theoretical Background

There are distinct strategies that are often utilized by special educators. Sheppard and Wieman (2020) state special educators often use direct instruction to teach math, and utilize scaffolding to provide support to students with math disabilities. However, Sheppard and Wieman (2020) highlight important distinctions between math education methods and special education methods that may conflict with outcomes for at-risk students. Some current math methods include using problem-based instruction which varies greatly from direct and explicit instruction. Further, some math researchers believe that the strategy “scaffolding” is malpractice due to scaffolding taking away opportunities for students to cognitively work through a problem (Sheppard & Wieman, 2020). Although there may be conflicting theories to mathematical instruction, Powell et al. (2022) highlighted various approaches that are essential components to teaching students with math difficulties. One approach highlighted was using the Concrete–Representational–Abstract sequence to utilize multiple representations of mathematical concepts. Another approach was including fact fluency. Powell et al. (2022) state that providing immediate feedback, modeling, and providing multiple opportunities to practice using both known and unknown facts. One final approach highlighted was the use of an attack strategy paired with schema instruction to provide explicit word problem instruction to students. With varying views and practices to math instruction, it is crucial to review literature to determine what methods and strategies work in tiered interventions for at-risk elementary students. In tiered interventions, it is almost universally followed to have three tiers of instruction being named, Tier 1, Tier 2, and Tier 3. According to Harlacher et al. (2014), Tier 1 instruction is universal, evidence-based core instruction that all students are exposed to. In rare cases, some students are excluded from Tier 1 instruction to receive a different level of instruction. However, in most cases, students at-risk and students with disabilities are included in the Tier 1 intervention. Next, Tier 2 interventions are usually between five and eight students, and follow an evidence-based intervention program or strategy. The Tier 2 intervention does not have to meet every day, and when the instruction does take place, it is usually no longer than 30 minutes (Harlacher et al., 2014). Lastly, Tier 3 instruction are the most intensive interventions a school has to offer. In general, Tier 3 interventions have daily meetings for periods longer than 30 minutes that follow an evidencebased program of instruction or strategy for a group no larger than four. This intervention can replace Tier 1 interventions in some cases (Harlacher et al., 2014). The majority of students receiving Tier 3 interventions are identified in special education. However, at the elementary level, many students are yet to be identified as having a disability, therefore placing a heavier emphasis on the efficacy of Tier 1 and Tier 2 interventions to keep students achieving closer to grade level expectations.

Focus of paper

This paper is focused on determining evidence-based practices of tiered math interventions that will provide the best opportunity for successful math outcomes for elementary students. Comprehensive definitions of each tiered intervention are provided in the definitions section and elaborated on in the theoretical background section, but the higher the number on the intervention, the more intensive the intervention will be. The paper will first review articles based on the type of math intervention being used. After the evidence-based tiered math interventions have been summarized, there will be a section that will discuss how the identified practices or approaches within the interventions could be used in various settings such as core or small group instruction to support students. Additionally, there will be a section in the paper that will discuss future research.

Importance of Topic

Currently, my school has focused heavily on professional development with literacy instruction. This has been great to learn about current practices that will help not only students that are struggling to read, but all students achieve higher levels of proficient reading. Unintentionally, professional development opportunities for math practices have not been available. Further, our school is shifting its approach to teaching through adapting multi-tiered systems of support (MTSS) in core subjects. With that, our school is shifting its approach to the way special education and interventions are provided. This shift in practice to MTSS and lack of professional development in math has myself wondering as the best ways to support students in math during this shift. This research paper will allow me to review literature of evidence-based instruction to find best practices for tiered interventions for at-risk students.

Definitions:

Tier 1 Intervention – The main component to tiered instruction, Tier 1 intervention is the evidence-based core instruction that all students are exposed to (Harlacher et al., 2014).

Tier 2 Intervention – Interventions that are in small groups usually no larger than 8, with instruction lasting usually 30 minutes. The intervention usually meets only a few days a week rather every day (Harlacher et al., 2014).

Tier 3 Intervention – Interventions that are taught in the smallest groups usually no larger than 4. Instruction is usually daily and taught for more than 30 minutes per sessions (Harlacher et al., 2014).

At Risk Student – A student that is performing significantly below their same aged peers and may have a disability under IDEA (Peltier et al., 2020).

Concrete-Representational-Abstract (CRA) Sequence – An explicit and systematic instructional sequence that teaches mathematics concepts through multiple representations such as drawings, numbers, and base-ten blocks (Powell et al., 2022).

Schema Based Instruction (SBI) – an instructional approach focused on strategy by classifying word problems into categories that could then be used to identify a specific word problem type (Jitendra & Hoff, 1996).

Mnemonic Device - a description or list of procedural steps formatted as an acronym to reinforce independent problem solving usually having the first letter in the mnemonic represent the first letter in the steps needed to solve a math problem (Miller et al., 2011)

Chapter II: Literature Review

Introduction

The following chapter will provide an extensive review of research articles of several instructional strategies and methods used in mathematics instruction. The chapter will be divided into three sections being math fact fluency research articles, concrete-representational-abstract sequence research articles, and word problem instruction research articles. The beginning of each section will begin with a table of studies. Each table will include a summary that will include core information for each article related to the participants, procedures, and results. After, the articles will be presented in chronological order which is the same order they are shown in their respective tables. In total, there are 14 total articles that are being reviewed. After the articles have been reviewed and summarized, the following chapter will provide implications for practice for Tier 1, Tier 2, and Tier 3 instruction based on the results from the articles reviewed.

Table 1

Summary of Math Fact Fluency Intervention Studies

Authors	Participants	Procedure	Results
Rave & Golightly (2014) Quantitative Tier 1	The study featured 44 fifth grade students. 11 of which students were receiving reading or math special education services. The intervention utilized a curriculum called Rocket Math multiplication and the intervention ran for 28 sessions over the course of nine weeks in the general education setting.	Rocket Math included pretest, posttest, placement, daily, and biweekly probes. Participants took placement probes to determine which level within the intervention they would begin at. Participants practiced single digit multiplication in pairs. Participants would play both the checker and the learner and they would switch roles after two minutes. Afterwards a one minute probe was administered to measure growth. Overall growth, was measured by the number of levels the participants passed in the intervention.	Results show that Rocket Math significantly increased students' multiplication math facts performance for both special education and general education students. Over the nine week intervention, the average levels passed in the intervention for general education students was 15.25 levels. For special education students, the average level growth was 12.55 levels. In order to pass a level, a student needed to meet their goal, which in most cases was 26 correct problems on the one minute probe.
Skarr, Zielinski, Ruwe, Sharp, Williams, & McLaughlin (2014) Quantitative Tier 3	The intervention featured three participants, a third grader and two fifth graders. One of the 5th grade participants was receiving special education math services. All three participants did not have the first 100 multiplication facts mastered.	The intervention provided oneon-one instruction. The participants received the direct instruction intervention for 30 minutes 2 times a week for a total of 19 to 23 sessions depending on participant progress. The participants' goal was to state a complete multiplication fact within 2 seconds. There were pretest, posttest, and daily timed probes to measure growth.	The study did not run a statistical analysis determine significant results. Participant 1 had a 141% increase in their performance pretest to posttest. Participant 2 had an 82% increase in their performance pretest to posttest. Participant 3, a student with a special education math goal, had a 63% increase in their performance pretest to posttest.

Gross, Duhon, Shutte, & Rowland (2015) Tier 1	The study featured 53 first grade participants across three different first grade classrooms. The study took place in the general education math setting.	The study aimed to measure reward systems used by classroom teacher. Each student received a written goal and graph for their addition to 10 probes that were timed for 2 minutes. Goals were taken from a rolling median from the 3 previous probes. Pretest data were collected from first daily practice probe. This intervention took place over 6 weeks. Data was collected every Tuesday and Friday as they were goal days. Classrooms were assigned to one of three groups being a collective performance reward group (DG), and individual performance reward group (IG), and a control group (EG).	All three groups had significant growth from pretest to posttest. The IG group, when comparing effect sizes, had the greatest gains of all the groups. Results support explicit timing (ET) as a viable classwide intervention.
Musti-Rao & Plati (2015) Quantitative Tier 1	The study took place in an inclusive 3rd grade classroom. There were 12 third graders that participated in the study.	Participants participated in two types of interventions for math multiplication facts. One intervention was a self-mediated iPad intervention, and the other was a detect-practice-repair (DPR) intervention. Students participated in both interventions for 10 minutes each over the course of eight days. Data was collected daily to measure student growth.	The iPad intervention had the greatest level of growth in terms of digits correct per minute compared to the DPR. Additionally, response rate of students in the intervention had students responding 18.5 times per minute in the iPad intervention compared to the 8.5 times per minute in the DPR intervention. Lastly, greater preference was on the iPad intervention for teachers and students over the DPR.

Berret & Carter (2017) Tier 1 Quantitative	This study focused on a multiplication math facts intervention through a computer assisted instruction called Imagine Math Facts – Timez Attack. The study included 63 3rd grade students ranging in multiplication skills of below proficient to above proficient.	The study used a multiple baseline across groups design, staggered baseline-intervention schedules. The participants were split into three groups. The intervention occurred two times per week for 20-30 minutes. The intervention occurred over the course of 12 weeks with a three week maintenance period. The type of instruction through Timez Attack was modeling, drill and practice, immediate and regular feedback, and adaptive. Data was collected each time the intervention occurred through a randomly generated multiplication probe.	Below proficient students increased fact fluency performance on a 1 minute timed test by 5 points from a level of 11 correct responses to a level of 16 correct responses. Near proficient, proficient, and above proficient increased by 5.5, 7.4, and 11.1 points respectively. Effect sizes indicate that students that use Timez Attack are very likely to experience significant improvements regardless of prior level/proficiency. Group scores maintained through the maintenance period.
Greene, Mc Tiernan, Holloway (2018) Quantitative Tier 2	Cross-age peer tutoring and fluency based instructional approaches. This study included 41 female participants in an all girl school. The participants were in 3rd, 4th, and 5th grade. 5th graders provided tutoring. Used Morningside math facts Addition and subtraction curriculum.	The intervention utilized cross age peer tutoring and fluency based instructional approaches. The curriculum used was call Morningside Math Facts Addition and Subtraction curriculum. The intervention occurred three times per week for 30 minute sessions. The intervention lasted 12 weeks which four of those weeks were for pre and post testing. Tutoring groups were based on baseline scores to make groups similar in skill level. Groups were then randomly assigned either the control or experimental group.	Pretest scores violated assumption of normality. There was a significant difference between control and experiment on WJ-III fluency subtest and fluency with target math facts from the intervention. The results provide evidence for using cross tutoring and SAFMEDS to increase fluency with math fact families.

Rave & Golightly (2014) The effectiveness of the rocket math program for improving basic multiplication fact fluency in fifth grade students: A case study

Rave and Golightly conducted this study in hopes to determine the effectiveness of the Rocket Math program in improving the multiplication fluency in elementary school students, specifically for fifth graders. This study featured 44 students from three different fifth grade classrooms. One important feature, is this school featured rotating classrooms. Meaning, the same teacher taught all three different groups their math instruction and conducted the math intervention. Of the participants, 33 students were in regular education programming and 11 students were in special education receiving learning support. Eight of the special education students were identified as Specific Learning Disability (SLD) and were receiving math or reading services. One student was identified as Other Health Impairment (OHI). The final two special education students were identified under both categories of OHI and SLD. Classroom 1 contained six of the special education students, classroom 2 contained five of the special education students, and classroom 3 contained none of the special education students. The design for the study was a pretest-posttest non-experimental design. Students acted as their own control for the study. Baseline procedures consisted of writing and placement probes. The writing probes served as a measure to determine how many numbers a participant could write in one minute. Depending on the amount of numbers that were written on this probe, a corresponding goal was set for the multiplication probes as the writing probe aided in determining how many problems would be able to be completed in one minute. Students then completed placement probes to determine what step in the Rocket Math program they would begin at. There are 26 steps, labeled using the alphabet, and students could begin at step A, G, M, or division depending how they scored on their placement probes.

After placement probes were conducted the intervention began. Students would practice two-five times per week over the course of nine weeks. In total, there were 28 sessions. On a practice day, students would work in pairs. One student would act as the learner, and the other student would act as the checker. The learner had a leveled practice sheet in front of them, and would recite the problem and give the answer out loud. The checker had the answer key, and listened for errors and hesitations. If a hesitation or error occurred, the checker recited the math fact and had the learner recite the math fact back. The learner then backed up three problems and continued the process. After two minutes had passed, the students switched roles. After practicing, the students completed a one minute probe in correspondence to the step they are on. If they meet or exceed their goal, they are then able to move onto the next level. If a student does not meet their goal they stay at the same level. If the student does not meet their goal five times in a row at the same level, they then move back down to the previous level. Lastly, every two weeks a two minute probe was administered that was not based on their level.

Data for the intervention was collected from the two minute probes and the leveled probes that occurred after the practice sessions. Across all students, the average amount of levels passed was 15.25. For the regular education students, this average was 16.15 and for the special education students this average was 12.55. This difference in levels passed is not significant. For the two-minute probes, each one was scored based on the number correct divided by their goal. When comparing the first two-minute probe to the final two-minute probe, the average percentage increase was 22.98% for all students. This average increase for all students was a significant increase and had an effect size of 1.61. When comparing the average increase for special education (M=21.09%) and regular education students (M=23.61%) for the two minute probes and this difference is not significant. Lastly, there was no significant difference between classrooms on the first and last two-minute probe.

One important note from this intervention is that cheating was an issue. The 44 participants included in this study were participants that followed all instructions and guidelines. At the beginning of the intervention there were 55 participants, but 11 did not follow grading instructions or cheated and were omitted from the study.

One limitation is that this intervention was only a nine week intervention and did not allow for students to complete all levels within the intervention. Another important limitation is this intervention did not have a maintenance period to track student performance post intervention.

Skarr, Zielinkski, Ruwe, Sharp, Williams, & McLaughlin (2014) The effects of direct instruction flashcard and math RaceTrack procedures on mastery of basic multiplication facts by three elementary students

The purpose of this study was to determine the effectiveness of direct instruction (DI) flashcard procedure along with a math racetrack procedure on the oral mastery of basic multiplication facts. The other purpose for this study was to determine effectiveness of implementing this type of intervention to both students with and without disabilities. This study featured three participants. Participant 1 was an eight year old third grade student. Participant 2 was a ten year old fifth grade student. Participant 3 was an eleven year old fifth grade student. All participants had yet to master all their basic multiplication facts. Additionally, participant 3 was the only student receiving special education services. He was receiving services for math, reading, and spelling. The intervention for participant 1 and 2 took place outside of school for 30 minutes per session two times per week. For participant 3, the intervention took place during school for 20-30 minutes per session two times per week.

The intervention began with baseline procedures. The interventionists gave a probe of all 100 basic multiplication facts. From this probe, target facts were selected from missed problems. These target problems were created into three sets of seven flashcards to practice. After baseline procedures then followed the DI and racetrack procedures. No instruction was given during baseline of the target facts.

The DI flashcard consisted of presenting 15 flashcards of which seven target facts and the rest were mastered facts. When presented a flash card, the participants needed to say the entire math fact correctly within two seconds. If this did not happen, the interventionist provided modeling and stated the entire fact and the participant repeated this back to the researcher. The interventionist then put the flashcard back into the pile near the front so the participant would see the fact relatively quickly again. This process continued until the participant answered the target fact three times in a row, then it would be placed in the back of the pile. The Math Racetrack procedure was a board game used with the target math facts. On the board game there were 28 spaces in a circle forming a racetrack for the participant to travel along. Each space contained a math fact. 14 of the spaces contained mastered math facts, the other spaces contained seven target math facts all repeating at least two times. For the participant to travel along the racetrack, they needed to state the entire math fact. If an error occurred, the interventionist stated the math fact and had the participant repeat it. The participant completed at least two laps around the track. Once set 1 facts were mastered, Set 1 facts then became "mastered" facts that the participants then reviewed with both the DI and Math Racetrack procedures. This followed for all three sets for each participant which consisted of three days of demonstrated mastery for a set of facts.

Data was collected across 23 sessions for participants 1 and 2 and 19 sessions for participant 3 using multiple baseline across the three sets of math facts. After baseline procedures and receiving DI and Math Racetrack procedures, all participants' scores increased on target math facts eventually obtaining mastery. Participant 1, 2, and 3 continued to showed mastery of all 3 sets of target facts for the final three sessions of the study. Pretest and posttest measures also indicated large increases in math facts. On the 100 point probe of math facts, participant 1 increased their score from 29 to 71 (141% increase) participant 2 increased their score from 55 to 100 (82% increase), and participant 3 increased their score from 38 to 62 (63% increase).

Gross, Duhon, Shutte, & Rowland (2015) A comparison of group-oriented contingencies for addition fluency

This study focused on the impact of independent and dependent group-oriented contingencies on addition fluency of first graders when it is used with explicit timing, goal setting, and feedback as a class-wide intervention. The participants included 53 first grade students from three different classrooms. Each of the three classrooms provided a different incentive systems. Three teachers' classrooms along with their students were used for the study. The first classroom had 17 students which acted as the control group. The teacher did not use contingency rewards, but did use goal setting and graphic feedback. The other two classrooms had 18 students each, and used a contingent strategy, goal setting, and graphic feedback. Additionally, of the classrooms that used contingency rewards, one classroom utilized a dependent group-oriented contingency, or a group performance reward (DG). The other used an independent group-oriented contingency or an individual performance reward (IG).

In the IG classroom, goals were given out on Tuesdays and Fridays and the students attempted to achieve them. The following morning, if they had beat their goal they will have received a sticker as their prize. Students accumulated stickers, and once enough were achieved, they were able to pick a prize and start over. Students in the DG classroom followed a similar procedure, however, the DG classroom differed on how the stickers were earned. Of all the students in the DG classroom, three students' probes would be selected. If those three students achieved their goal, all students will have received a sticker. As mentioned above, the control classroom did not follow any kind of reward strategy. Each classroom was also using the same procedure to collect participant data on addition fluency.

Students' success in addition fluency was measured in digits correct per minute (DCPM). Students received a goal Tuesday and Friday that they attempted to beat through a 2 minute ET probe. The goal was determined using a rolling median score from taking the median score from the students' last three probes. Data collected and used were from the Tuesday and Friday probes as these were the days used for the reward contingency, a pretest probe, and a final posttest probe. The intervention and data collection period lasted six weeks.

After the six week period of ET probes, when doing a paired-samples t test to determine the impact of each respective intervention. All three groups (IG, DG, and control) had significant improvements in scores in DCPM from pretest to posttest probes. The IG group, when comparing effect sizes, had the greatest gains of all the groups. The DG group had the highest average of students achieving their goals on their probes, however this difference was not statistically significant.

Musti-Rao & Plati (2015) Comparing two classwide interventions: Implications of using technology for increasing multiplication fact fluency

This study aimed to evaluate the effects of two different classwide interventions, detectpractice-repair (DPR) and self-mediated iPad instruction, on basic multiplication math facts of third grade students. The study also aimed to determine the ease of implementation of both interventions to a classroom setting. There were 12 total participants out of 21 third-grade students from a classroom that used a co-teaching model. There were 14 students receiving the intervention, two of which were excluded, and the other seven were receiving pull-out services during the time of implementation. The interventionists for this study were the third-grade classroom teacher and the teaching assistant.

The intervention assessment materials included various items. The first of which were screening probes. There were two versions to serve as a pretest and posttest measure. The screening probes consisted of 36 multiplication problems (single-digit by single-digit with factors of 2-9) and students were given 2 minutes to complete the probe. In addition to screening probes, there were assessment probes. The assessment probes consisted of the same types of problems as the screening probes. Students were given 1 minute to complete the assessment probes. There were three different versions of each assessment probe that went to each condition. The DPR condition received set A, the iPad condition received set B, and the control condition received set C. Students were probed on set A and set B daily, and received the set C probes every 3-4 days. There were 36 problems on each probe that came from a pool of a 12 problems.

To evaluate the effectiveness of both interventions, there were multiple measures used. The measures used were digits correct per minute (DCPM), response rate, and practice time. DCPM was used to score assessment and screener probes. Response rate was used to calculate the amount of math facts practiced during each interventions practice phase. Lastly, the practice time measure was used to calculate the average amount of time students were practicing for each intervention.

The intervention spanned across eight days of instruction. Both interventions were administered daily for 10 minutes each. Additionally, a maintenance probe was given three days after the intervention ended and a generalization probe was given one week after the intervention ended. The class was divided into two groups of seven students. While one group received the DPR intervention the other group received the iPad intervention. The DPR intervention took place at a table by a SMART board. Students first did the detect phase which was completing 12 problems within 3 seconds as shown on a PowerPoint. The results of the detect phase informed the practice phase as students then used problems they did not get correct to do a “Cover-CopyCompare” activity. The repair phase was a timed assessment probe of the practiced problems plus additional problems. Lastly, students graphed their progress, and if they scored higher than 30 they received a sticker for their sticker chart. The iPad intervention consisted of students practicing the 12 multiplication facts through the Math Drills application. Students first reviewed the problems on the application through a presentation. Then the students practiced the problems in a practice mode on the application. Lastly, students were then tested in the app on the problems in a test mode. After completing the test mode, the students logged their progress and then completed the assessment probe.

At the beginning of the intervention, seven students were performing with less than 14 DCPM and five students between 14-31 DCPM. By the end of the intervention, 10 students reached mastery and two students moved into the 14-31 DCPM range. Results of the intervention show that greater gains in DCPM happened in the iPad condition compared to the DPR condition. Maintenance and generalization data show that students were able to maintain scores three days after intervention but also generalize their knowledge by responding to the inverse multiplication problems one week after probe. Response rate results indicate that students were responding more on the iPad condition (18.5 responses per minute by the 8th session) compared the DPR condition (8.5 responses per minute by the 8th session). Results from the practice time indicate very similar amounts of time practicing across the eight sessions with the DPR condition averaging 39.6 minutes and the iPad condition averaging 40.1 minutes. Lastly, although both interventions were successful, the iPad intervention was deemed the more preferred method among both teachers and students.

Berrett & Carter (2017) Imagine math facts improves multiplication fact fluency in third-grade students

Berrett and Carter (2017) aimed to investigate whether the Timez Attack program was effective in teaching multiplication fact fluency and automaticity to third-grade students. This study utilized 63 third graders. These students had mixed abilities in regards to their mathematics abilities, and of the participants, 11 were below proficient, 21 near proficient, 15 proficient, and 16 were above proficient based on results of a state-specific standardized assessment. Three groups were created that students were randomly assigned to. Due to the design of the study, groups began the intervention at different times. The use of a staggered start for the intervention was to better establish causality between the intervention and learning outcomes. Group 1 completed baseline procedures for two and a half weeks, then used Timez Attack for the remaining seven and a half weeks. Group 2 completed seven baseline assessments over three and a half weeks, then used Timez Attack for the remaining six and a half weeks. Finally, group 3 completed nine baseline assessments over four and a half weeks, then used Timez Attack for the remaining five and a half weeks.

The intervention utilized a game from Imagine Math Facts called Timez Attack. Timez Attack teaches multiplication facts through putting students in a 3D world and in order to progress through the game, multiplication facts need to be answered. The game is individualized to the students' ability. Before a student is able to play the game, a pretest from the game is administered. This is to determine which facts are mastered and unmastered. Additionally, in game performance is used to further differentiate which facts need more practice. This intervention had students play the Timez Attack game over the group's respective span two times per week for 20 minutes per session. If students finished the game, they replayed the game in "Ninja Mode" where the difficulty was raised by giving students less response time in the game. Students were not allowed to play Timez Attack outside the intervention sessions.

As mentioned above, baseline procedures lasted for different amounts of time depending on the group. During the baseline phase, students completed two multiplication assessments per week prior to receiving their computer time. The assessment was a randomly generated assessment that contained 30 random math fact problems using the digits 1 through 9. After baseline, students still continued to take the multiplication assessment prior to logging in to playing Timez Attack. This was to limit any immediate carryover from a Timez Attack session and be a more accurate assessment of student performance. Once the intervention concluded there was a maintenance phase that included students' spring break. As was during the intervention, students were not permitted to play Timez Attack during the maintenance phase. During the maintenance phase, students completed two assessments per week.

Results for this intervention were gathered by computing mean scores for each study group for each assessment. All groups experienced improvement throughout the intervention. Group 1, which had the most time in the Timez Attack game had a baseline average of 13.0 and a maintenance average of 23.1. The shows improvement along with maintaining their skills gained for three weeks post intervention. Groups 2 and 3 also had similar improvements comparing their baseline and maintenance averages.

Additionally, scores were grouped and averaged from assessments 1 and 22 based on their proficiency level. All proficiency groups improved from assessment 1 to assessment 22. The below proficient group increased by 5 points, the near proficient group increased by 5.5 points, the proficient group increased by 7.4 points, and the above proficient group increased by 11.1 groups.

Lastly, effect sizes were calculated for each of the groups' scores by use of nonoverlap of all pairs. Students in group 1 had an effect size of .97, group 2 had an effect size of .96, and group 3 had an effect size of .88. These effect sizes mean that students who use Timez attack are very likely to experience significant improvements in multiplication fact fluency.

Although this study highlights the success of the program Timez Attack. The demographics provide limiting information on the students themselves. The only measure of students' math ability prior to the intervention is a standardized math assessment. There is no included information on whether the students who participated in the study have learning disabilities.

Greene, Tiernan, & Holloway (2018) Cross-age peer tutoring and fluency-based instruction to achieve fluency with mathematics computation skills: A randomized controlled trial

The purpose of this study was to increase fluency in mathematics skills through cross-age peer tutoring and fluency-based instructional approaches. The study included 41 participants that were in grades third, fourth, and fifth. It is worth noting that all participants were female as the school was an all-female school in Ireland. Between all of the participants, none were fluent in their addition skills. The intervention featured an addition and subtraction curriculum called

Morning Side Math Facts: Addition and Subtraction curriculum, flashcards for target facts, and tutoring folders. There were multiple measures used to measure the effectiveness of the intervention.

A stratified randomized control trial was used. Students in third and fourth grade were stratified into pairs based on their pre-test scores on the Woodcock Johnson Test of Achievement, Third Edition (WJ-III) on the calculation and mathematics fluency subtests. Pairs were made by assigning them to the person who had the next closest standard score. From here, groups were randomly assigned the control or experimental group. 14 participants were in the control group and 15 were in the experimental group. The intervention was carried out over a period of eight weeks with an additional four weeks for pretest and posttest procedures. All fifth grade participants received training prior to being a tutor for the study. Training was done by the researcher of this study. After the training, all tutors demonstrated at least 90% accuracy for completing the tutoring procedures which was the minimum threshold they needed to reach. Tutoring sessions were conducted three times per week for a duration of eight weeks with each session lasting 30 minutes. Say All Fast Minute Each Day Shuffled (SAFMEDS) was used in the tutoring sessions to build addition. SAFMEDS is a frequency-building instructional strategy that aims to increase the rate of correct responding to math facts. SAFMEDS uses flashcards for targeted math facts. In the intervention there 16 total sets of flashcards with target facts that the tutee needed to try and work through. To move onto a new set a tutee needed to answer have at least 50 correct responses per minute. During the one minute timing, the tutor would place correct facts in one pile and incorrect facts in a different pile. After the 1 minute timing, the tutor would present the flashcard and the tutee would respond. If no response, the tutor gave the answer and the tutee repeated. This process was done for each incorrect fact. Once all incorrect facts were gone through, the timer would be reset and another attempt would be made. Data was collected at the end of each one minute timing by the tutor or tutee for each correct and incorrect response. Lastly, if students were showing target behavior of achieving their goal, working well, working fast, or listening they could receive a sticker for their sticker chart to redeem for a prize.

The three groups' posttest scores on mathematics measures were then compared to their pretest measures through a MANCOVA. The results indicated a significant difference between groups. The experimental group had significantly higher differences in their posttest measures of the WJ-III subtest for mathematics fluency and fluency with target math facts. This means that after the intervention, students who were in the experimental group were performing significantly better than the students in the control group. One large limitation worth noting is that the control group received no additional instruction as an intervention. The experimental group was receiving an additional 30 minutes of instruction three times per week in comparison to the control group.

Table 2

Summary of Word Problem Interventions

Author	Participants	Procedure	Results
Jitendra, Rodriguez, Kanive, Huang, Church, Corroy, & Zaslofsky (2013) Quantitative Tier 2	The study included 136 participants that were in third-grade. In addition, there were 16 participants who were in special education. 72 participants were in the Schema-based instruction intervention (SBI), and 64 participants were in the standards-based curriculum (SBC) intervention.	Participants in the SBI received instruction on three different schemas for addition word problems. In addition to the schema instruction, the students also received a mnemonic device to aid problem solving. The SBC group received instruction on word problem strategies and other computational skills. There were pretest, posttest, and maintenance measures used.	Results show that word problem solving increased for both groups. Participants who had higher pretest scores had the greatest growth throughout the intervention. The effect size of the SBI group was higher than that of the SBC group meaning that SBI had a greater impact on word problem solving than SBC.
Flores, Hinton, & Burton (2016) Quantitative Tier 3	This study included three third-grade students receiving tertiary or Tier 3 interventions in mathematics. In order to participate, participants needed to demonstrate proficiency in addition and subtraction with and without regrouping.	The students received instruction four days per week for 20 minutes outside of the general education setting. There were four phases of instruction. One phase was to teach problem types (SBI), the other three followed the CRA model. There were a total of 20 assessment probes.	All three students improved their problem-solving performance and achieved mastery using intervention that contained CRA, FAST strategy, and schema-based instruction.

Alghamdi, Jitendra, & Lein (2019) Quantitative Tier 3	This study included three 5th grade participants in special education. The participants needed to demonstrate competency in their multiplication facts in order to participate.	The participants received the one-on-one the intervention four times a week for 30 minutes per session. The intervention featured a six-lesson unit on solving different multiplication problem types (schemas). Each lesson would take at least two sessions to complete. There were pretest, posttest, and maintenance measures.	The results of this study indicate that all students increased their problem solving skills from the schema based instruction intervention. In addition, each participant's data was used to determine effect size, and for each participant there was a strong effect size.
Powell, Berry, Acunto, Fall, & Roberts (2022) Quantitative Tier 2	The study included 109 third grade students that were initially screened. Randomly assigned Pirate Math intervention or Business as usual. The third grade students were split into even groups for the intervention.	The intervention lasted 16 weeks that met 3 times per week for 30 minutes. The purpose of the intervention was to assess Pirate Math Equation Quest as a problem solving intervention in a small group format.	The Pirate Math intervention group significantly outperformed the business as usual group in regards to problem solving ability when comparing pre and posttest measures.

Jitendra, Rodriguez, Kanive, Huang, Church, Corroy, & Zaslofsky (2013) Impact of a smallgroup tutoring interventions on the mathematical problem solving and achievement of thirdgrade students with mathematics difficulties

The purpose of the present study was to determine the effectiveness of small-group tutoring on word problem solving performance of students with math difficulties, using either schema-based instruction (SBI) or a school-provided standards-based curriculum (SBC). This study pulled participants from 12 different elementary schools from the same school district. There were 2 important exclusionary factors. First, if the third-grade students were not at a beginning second-grade reading level they were not able to participate. Secondly, if the students received their core math instruction in an alternative setting, they were also excluded. In total, there were 136 participants, 72 of which were in the SBI group and the other 64 were in the SBC group. In addition, there were 16 students who were in special education that participated in this study.

The participants in both groups received their 60 minutes of core instruction. After, both groups then received supplemental instruction depending on the group they were assigned to, either being SBI or SBC. Participants in the SBC group received instruction in place value, addition and subtraction, and word problem solving strategies that were included in their text book. These skills were broken into four separate units that participants completed over the span of the study. The participants in the SBI group had five instructional units that they worked through throughout the intervention. The length of the entire intervention was 21 lessons. This study aimed to teach students to identify the different word problem types, or schemas.

The additive schemas for this study were change, group, and compare. The first three units followed the same structure. The first lesson of the unit presented the schema without the unknown information in the word problem. This allowed the participants to focus on the schema itself and not solving the problem. After, the following three lessons had explicit instruction on solving the word problem with visual aide called a schematic diagram. For the final lesson of the unit, the student needed to generate their own schematic diagram to use on the word problems. Unit 4 was a comprehensive review of all three word problem schemas. Lastly, unit 5 was a unit that focused on two-step word problems. The instruction on word problem types came in two parts. The first part of instruction was called “problem schema” instruction. This instruction included no unknown information to solving the word problem. Rather this instruction focused on the identifying of the word problem. After this instruction was completed, the instruction moved into “problem solution” instruction. This instruction focused on students solving word problems that contained unknown information. Here, they would need to identify the problem type, then solve the word problem. This was supported through the mnemonic device of FOPS. With first teaching the word problem schema, then applying a metacognitive strategy, FOPS, to solving the word problem, the SBI prompted and guided students through the problem solving process of the various types of word problems.

To measure the effectiveness of the intervention several measures were given as pretest and posttest measures. First, MAP mathematics and reading rests were used as pretest and posttest measures. The MAP mathematics subtests measures number sense, estimation, computation, statistics, and probability. The MAP reading subtest measures word recognition, vocabulary, reading comprehension, and literature. The next measure pretest and posttest measure was a mathematical problem solving test that included 9 one-step problems and 3 twostep problems. Students were given 50 minutes to complete the test and the problems were read aloud. This measure was also used as a maintenance measure to be used six weeks after the intervention. The last measure used was an addition and subtraction automaticity measure. The measure was a 4 minute timed test with 75 problems that contained addition and subtraction with digits 0 to 18.

The results of this study were regardless of the SBC or SBI condition, WPS performance increased for both groups. However, the results indicate that pretest WPS performance determined effectiveness of the intervention for both groups. Students who achieved higher pretest scores received the most gains if they were in the SBI group and maintained their skills the most 6 weeks after the study. It is an important distinction because, students with math difficulties who have mastered the computational skills required for word problems benefitted the most from SBI. Lastly, students who were in the SBI group had a relatively higher effect size compared to the SBC group in maintaining their WPS skills. Meaning, the problem solving strategies from SBI had a greater effect of staying with the student after instruction than compared to SBC. One important limitation is that this study did not distinguish results from students with math difficulties, students with reading difficulties, and students that have both reading and math difficulties. Future research would benefit from this type of research style that also focuses on the SBI intervention for these groups of students.

Flores, Hinton, & Burton (2016) Teaching problem solving to students receiving tiered interventions using the concrete-representational-abstract sequence and schema-based instruction

The purpose of the present study was to combine schema-based instruction and the concrete-representational-abstract (CRA) sequence to provide tiered intervention for students at risk for failure. This study featured three third-grade students' tertiary interventions in mathematics. The intervention for the study was four days per week for 20 minute sessions during an afterschool care program that was offered by the school. One important note is that each participant demonstrated fluency in addition and subtraction with regrouping prior to beginning the additive word problem intervention. Each participant received one-on-one instruction and had staggered starts to the intervention.

Participants completed probes during the intervention to assess the effectiveness of the learning in the intervention. To properly assess their learning, students were probed prior to daily instruction. In addition to the quantitative data, qualitative data was acquired by interviewing students throughout the intervention. The interview was used to ask students to explain how to solve problems and how to use the representations of CRA to solve problems.

The intervention included four phases of explicit instruction. The phases of instruction included teaching three problem types (part-part-whole, comparison, and change) using schemabased instruction, concrete instruction with word problems, representational instruction with word problems, and abstract instructions with word problems. In addition, a mnemonic device was used as a problem-solving strategy called FAST (Find what you are solving for, Ask "what are the parts of the problem" Set up the numbers, and Tie down the sign). The FAST strategy was used during all three phases of the CRA sequence. In addition to the CRA sequence, SBI was utilized. Throughout all sequences, problems were focused around three different word problem types that the students were solving. The three additive schemas were, part-part-whole, comparison, and change. To teach each problem types, word problems would be drawn or represented to portray the problem. From here, the problem type would be identified, and then the problem would be solved for.

The first participant, Carla, had an immediate change in performance once instruction for the intervention began. Carla's baseline scores across 5 probes was 10%. By the 16th probe Carla had demonstrated mastery for the intervention and she demonstrated maintenance of the skill post intervention. The second participant, Tim, also had an immediate change in performance once they began receiving the intervention. Tim's average baseline score across 8 probes was 0%. After 10 probes, Tim had demonstrated mastery of the skill, and demonstrated maintenance post intervention. The final participant, Trey, also had a change in performance once beginning the intervention. Trey's average baseline score across 14 probes was 8%. Trey's demonstrated mastery for the intervention after the 12th probe. Trey had the lowest maintenance score of 75%. The most difficult part for each participant was the extraneous information in word problems. This qualitative information was gathered through interviews. Lastly, the overall effect size of the intervention using Tau-U was a .94. This is a strong effect size meaning the intervention was very effective and impactful for increasing problem solving skills.

One limitation for this study is that the researcher was also the one providing the instruction. Future research should have a classroom teacher do the administering of this type of intervention. Next, the research design, multiple-probe across students, prevents the comparison of the results to be generalized. Lastly, CRA and SBI are known to be researched based instructional strategies, however there is limited research on the effectiveness of these two strategies combined. More research combining CRA and SBI with larger groups would be ideal for understanding its overall effectiveness.

Alghamdi, Jitendra, & Lein (2020) Teaching students with mathematics disabilities to solve multiplication and division word problems: The role of schema-based instruction

The purpose of the present study was to further determine the effectiveness of schemabased instruction on 5th grade math students being identified as having a math disability. This study used three fifth-grade special education students who are below the 10th percentile in math performance on state assessments, demonstrated competency on multiplication facts, and scored 50% or lower on a multiplication word problem-solving assessment. Selecting participants in this manner allows the researchers to get more reliable results on the effectiveness on their word problem intervention as they eliminate participants not knowing multiplication facts as a limitation to performance on intervention assessment measures.

The intervention would take place four times a week for 30 minutes per session. Participants worked individually with the researcher. The unit created was a 6-lesson unit that focused on solving different types of multiplication word problems, and each lesson would take two sessions minimum. The unit used a schema-based instruction (SBI) approach. In doing so, the lessons featured explicit instruction, modeling of thinking and problem solving, and opportunities for feedback and discussion with the participant. Although each word problem could be solved by creating a multiplication equation, SBI analyzes the semantic features of the word problem to organize the types of problems. The semantic features, or types of word problems solved were equal groups, unit rate, and arrays. In addition, SBI often features a mnemonic device to help students' remember the steps involved in solving a problem. This intervention used FOPS as their mnemonic device: Find the problem type, Organize the information in the problem using a diagram, Plan to solve the problem, and Solve the problem. Lastly, the intervention also featured the use of multiple representations to model the three different types of word problems.

Through using SBI, the goal was to have the participants apply the problem-solving procedures to the three types of multiplication word problems. The procedure that was hoped to be learned goes as follows. First was to have participants identify the type of word problem being presented. Next was to have the participants represent the problem either through drawing to visualize the equation and provide a visual to what needs to be solved for. Then, the participants would determine the strategy to solve the problem. The final step would be to have the participants check their solution. As mentioned above, this procedure closely follows the mnemonic device as explained above.

In order to appropriately measure the effectiveness of the intervention assessments were administered throughout the intervention. As part of the study design, the intervention began at different times for each participant. As one participant began to have success in the SBI intervention, the next student would begin. This was done, so each participant could act as a control for each other. During baseline, students would simply complete the Word Problem

Solving (WPS) tests. Participants would not receive feedback or and SBI word problem instruction during this phase. During the intervention phase, participants would be administered a WPS test at the end of a lesson. Lastly, there was a maintenance phase where students were administered the WPS tests one to three weeks post intervention. Like the baseline phase, the maintenance phase did not provide SBI instruction or feedback on WPS tests.

Results from the study showed that all three students showed higher performance on solving multiplication word problems when compared to their baseline performance. Participant 1 averaged 34.7% on their baseline scores. There was an increase of 57.2% on participant 1's intervention scores averaging 91.9%. Participant 1 scored 90% on their maintenance WPS tests. Lastly, effect sizes of participant 1's performance indicate that the intervention was highly effective. Participant 2 averaged 43% on their baseline scores. There was an increase of 45.7% on participant 2's intervention scores averaging 88.7%. Participant 2 scored 92.4% on their maintenance WPS tests. Lastly, effect sizes of participant 2's performance indicate that the intervention was highly effective. Participant 3 averaged 10.2% on their baseline scores. There was an increase of 62.2% on participant 3's intervention scores averaging 72.4%. Participant 3 scored 84.7% on their maintenance WPS tests. Lastly, effect sizes of participant 3's performance indicate that the intervention was highly effective.

There are some important limitations in this study. First of all, the target skill of this intervention is a 3rd grade standard, meaning these results are harder to generalize due to the participants being in 5th grade.. Additionally, there were only three participants in the study making this an extremely small sample size.

Powell, Berry, Acunto, Fall, & Roberts (2022) Applying an individual word-problem intervention to a small-group setting; A pilot study's evidence of improved word-problem performance for students experiencing mathematics difficulty

The purpose of the present study was to determine whether the implementation of a schema word-problem intervention with math difficulties would lead to improved word-problem performance. The participants in the study featured 76 students from 19 different third-grade classrooms all experiencing math difficulties in word problems. The 19 classrooms had 4 participants in each classroom making 19 groups. Each group was then randomly assigned either the Pirate Math Equation Quest (PMEQ) word-problem intervention or business-as-usual (BAU). Eight of the original 76 students were not able to finish the intervention, therefore leaving 68 final participants.

The intervention lasted 13 weeks with three sessions per week each lasting 30 minutes. With that, there were a total of 39 sessions completed. As this is a schema-based intervention, the intervention focused on the equal group multiplicative word problem type and three additive word-problem types: total, difference, and change. The intervention featured five activities that were completed during each session. Lessons 1-30 featured addition and subtraction flashcards and the final 9 lessons after featured multiplication and division flashcards with numbers 0 to 11. Participants would complete one-minute probes and graph their results. Next, participants would complete an activity called equation quest. Here, for two to five minutes, participants would receive instruction and work on solving equations. The purpose was to help students understand the reason for the equal sign and the importance of balancing equations. After this, participants would complete Buccaneer Problems. Here is where the interventionist led the schema instruction through three Buccaneer Problems. The mnemonic device "RUN" was used. The steps in RUN are: Read the problem, Underline the Label and cross out irrelevant information, and Name the problem type. For each of the schemas or word problem types, students learned to apply an equation to the problem and to mark "X to show the missing information or to the participants would be the "treasure." Then, students would complete Shipshape Sorting. This activity allowed students to work on identifying the different types of word-problem types (schemas) that were presented during the Buccaneer Problems. As the title of the activity suggests, this is a sorting activity. The students would sort word problem schemas into four piles. This activity started during the seventh lesson. The last activity for each sessions was called the Jolly Roger Review. This activity provided a comprehensive review of all things covered during the session. After working for three minutes, the interventionist would go over the correct responses with the small group. The BAU group did not receive any intervention or instruction. These students simply received their regular mathematics instruction. The regular classroom instruction did incorporate classwide word-problem instruction that did incorporate mnemonic devices, and key word clues.

In order to determine the overall effectiveness of the intervention several measures were administered to the participants. First, baseline or pretest measures were administered. This was spanned across two sessions. The assessments were standardized tests from the state of "Texas called Texas Word Problem – Part 1 & 2" and "State of Texas Assessments of Academic Readiness (STARR) – Part 1 & 2." These same assessments were administered as the posttest measure as well.

Results show that participants in the PMEQ group significantly outperformed the participants in the BAU group in regards to word-problem solving. These results indicate students with math difficulties benefit from SBI in a small group setting. Additionally, with these results, this intervention provides a realistic Tier 2 intervention that could be utilized by schools. This study mimics small group instruction that is commonly offered at the Tier 2 level as it meets for 30 minutes and doesn't meet every day of the week. It is worth noting this study aimed to replicate the results of this same study design that were seen at the one-on-one instruction level. This study found similar results meaning this intervention could be used as a Tier 2 or Tier 3 intervention. One important limitation is that this study was a pilot study. Meaning, this study should be replicated numerous times and in those replications look at different demographics and group sizes. Another limitation is that this study does not look at the performance of students that are in special education. The study indicated that there were 27 students in special education in the study, however their performance as a group is not noted.

Table 3

Concrete-Representational-Abstract Sequence (CRA) Studies

Flores & Franklin (2014) Quantitative Tier 3	Six fourth grade students, not receiving SPED services, but are at risk. The Tier 3 program takes place for a 30 minute period two times a week.	The program consisted following CRA-SIM. Although the number of lessons was not mentioned, there were seven assessments given throughout the study. The mnemonic (SIM) was the RENAME strategy.	$F(1, 5) = 11.53$, $p<.02$, meaning CRA-SIM had a significant difference in student's growth over time.
Flores, Kaffar, & Hinton (2019) Quantitative Tier 3	29 participants ranging from 4th grade to 7th grade. Of them, 15 were identified with disabilities. Students were a part of a summer intervention program.	The participants were then randomly divided to the DI group or CRA-SIM group. The program ran four days a week for four and a half hours. CRA-SIM group and DI group received instruction for 50 minutes each day in groups of four to six. Progress was measured through timed probes,	No significant differences between the groups in regards to pretest vs posttest performance and computation achievement. Significant change in student performance across both groups. CRA-SIM outperformed DI group slightly.
Flores & Hinton (2022) Quantitative Tier 2	Five Second grade students receiving Tier 2 interventions achieving below 70% on addition concepts. The groups met 3 days per week for 25 minutes.	The instructor taught the small groups in the classroom. The instructor would teach until mastery. The program followed 12 lessons following CRA-I in hopes to increase number sense and understanding of addition. Lesson eight introduced the mnemonic strategy for abstract instruction.	Across all groups and students, every participant achieved mastery and maintained skills post interventions within a natural setting.
Hinton & Flores (2022) Quantitative Tier 1 and 2	This study featured two implementations over two years with two groups of second-grade students. The first group was five students. The second group was the teacher's entire class.	The purpose of the intervention was to teach additive reasoning to then increase fluency of adding. Intervention follows a CRA-I model to teach additive reasoning. The intervention followed 12 lessons. Lessons 1-6 followed CRA-I, lesson 7 introduced a mnemonic strategy "FACTS." The remaining	From the first group, all students achieved mastery, and continued maintenance of target skill after the intervention. Additionally, the whole class had more fluency gains when compared to a class that did not use the additive reasoning intervention.

		lessons were using FACTS to solve problems.	

Flores & Franklin (2014) Teaching multiplication with regrouping using the concrete-representational-abstract sequence and the strategic instruction model

Flores and Franklin conducted a pilot study to determine the effectiveness of Concrete-Representational-Abstract (CRA) sequencing with the Strategic Instruction Model (SIM) to teach two-digit by two-digit multiplication to elementary students receiving tiered interventions in a response to intervention (RTI) framework. The study took place in an elementary school and was conducted during an after-school intervention program within a general education setting. This program was part of the schools tertiary or Tier 3 intervention program. The CRA-SIM instruction lasted 30 minutes and occurred two times a week over the course of seven weeks. The participants were six fourth grade students who have not been referred or enrolled in special education programming. The students demonstrated that their skill level was between one to two years behind their grade level. Additionally, their benchmark assessments demonstrated that they were not making sufficient progress.

The materials for the study included a teacher’s manual, student learning sheets, place value mats, base-ten blocks, and curriculum-based assessments. The place value mats also contained visual supports to aid students in solving two digit by two digit multiplication problems with both concrete objects and drawings. In total, there were ten lessons. As this is a CRA-SIM intervention, the lessons were broken into different stages in the sequence. Lessons one through three focused on the concrete representations. Here students would solve two digit by two digit multiplication problems with base-ten blocks. Lessons four through six was the representational sequence, and students solved two digit by two digit multiplication problems with drawings. Next, lesson seven introduced the RENAME strategy. Lastly, lessons eight through ten was the abstract sequence, and students would solve two digit by two digit multiplication problems with numbers while using the RENAME strategy. Students were only allowed supports in regards to which part of the sequence they were in. For example, base-ten blocks supports could only be used during the concrete instruction sequence.

The beginning of lessons began with an administration of a two-minute probe. In total, seven assessments were given out over the course of the intervention. After the probe, lessons followed this presentation. Instruction began with an advance organizer to allow the teacher to preview the lesson and concepts with students. After, the teacher began demonstration. Here, the teacher would demonstrate the procedure needed in the lesson by modeling the procedure and thinking aloud. Then, the teacher began guided practice where students joined in doing the procedure to solve the multiplication problems. Similarly to demonstration, the students would join in the problem solving process by stating which step comes next and saying their thinking out loud. Next, the teacher began independent practice. Here, students would solve problems independently and the teacher would not give any prompting, teaching, or guiding to help students solve problems. Lastly, the lesson would conclude with a post organizer where the teacher would review all the content that was covered throughout the lesson.

In order to determine the effectiveness of the intervention, curriculum-based assessments were given, as a pretest, posttest, and throughout the intervention. Probes were scored using digits written correctly. Student progress was measured by the change in percentage of digits written correctly. When analyzing pretest and posttest measures, results demonstrate that CRA-SIM made a statistically significant difference in students' growth in the percentage of correct digits writing for two digit by two digit multiplication problems. When looking at individual student growth, four of the six students made consistent growth throughout the intervention. One student's progress is unclear when looking at the graphed data of their progress. However, after instruction the student was able to complete a whole problem correctly whereas prior to the intervention the student was only able to write one digit correctly across many problems. Another student had computation errors that impacted their ability to complete problems correctly. It is worth noting that this progress was measured from 30 minute lessons that occurred two times per week across the course of ten sessions because there were significant gains made in a very limited about of time.

One limitation of this study is the sample size. With the study only having six participants the sample size is small. This type of study would need to be replicated with larger numbers. Additionally, CRA-SIM was not compared to any other type of intervention. The results only showed that CRA-SIM was an effective method. Lastly, the instruction for this intervention came from an instructor who has deep knowledge and a lot of experience with CRA-SIM whereas that may not always be the case with teachers.

Flores, Kaffar, & Hinton (2019) A comparison of the effectiveness of using CRA-SIM vs. direct instruction to teach multiplication with regrouping

The purpose of the present study was to compare Concrete-Representational-Abstract (CRA) sequence with a Strategic Instruction Model (SIM) against Direct Instruction to teach multiplication with regrouping. This study featured 29 participants in fourth through seventh grade. Additionally, fifteen of the students were identified as special education students. For participants to be a part of the study, students needed to demonstrate proficiency in basic multiplication, addition with regrouping, and multiplication involving one-digit numbers. From here, the members were randomly assigned to either CRA-SIM group or the DI group. The instruction for this study took place during a summer remedial intervention program at a combined elementary and middle school setting. Instruction for this study occurred for 50 minutes each day during the summer program. The program ran for six weeks for four days per week. Students were in groups of four to six when they received their small group instruction for CRA-SIM or DI.

The DI group followed a program called the “Corrective Mathematics Multiplication.” This program had a script or presentation that the teacher was then able to follow and present the material on a whiteboard to the students. Students had access to a student workbook within this program. This included sections where students had activities related to the multiplication procedures related to multiplication with regrouping, mental computation, place value, addition with regrouping, word problems, and multiplication with regrouping. These skills were practice and embedded within each lesson.

In general, DI has more oral responding, and opportunities to practice with repetition of solving problems using a procedural strategy. In the present study, DI utilized scaffolding through using grids and boxes to support regrouping and multiplying procedures throughout the problem and providing problems that were partially completed for the students to solve. As students progressed through lessons and instruction, these supports were taken away and students needed to solve the problems without any supports given. Further, as mentioned earlier, DI utilizes oral responding, so students needed to also provide oral responses on top of their written responses to solving problems. A typical DI lesson began with practicing the following skills: multiplication facts, addition with regrouping, place-value tasks, and word problems. These skills are essential pre-requisite skills needed for the next section of the lesson, which focused on the procedures regarding multiplication with regrouping. Procedures were explained and modeled with visual supports and completed problems, but as more examples were completed, the scaffolded supports were removed as well and students were expected to complete problems on their own. As students were solving the problems written and oral responses were needed. When responses were given incorrectly by the participants, teachers would provide immediate corrective feedback to model the correct response. Then the participants would respond correctly.

The CRA-SIM group followed an instructional manual that included procedures and behaviors teachers will be teaching each lesson. There were also base-ten blocks, a place value mat that can be projected on a whiteboard, and a Smart Board to use magnetic blocks or draw representations. Students had access to their own set of base-ten blocks, a multiplication mat for organizing base-ten blocks, learning sheets, and a progress chart to record their daily progress. The learning sheets had three sections which were demonstration, guided practice, and independent practice. The problems on the learning sheet had problems expressed as words and using symbols. The intervention was spread across 20 lessons. Lessons 1 through 12 only contained multiplication problems, however beginning on lesson 13 addition and subtraction problems were introduced to have students begin working to discriminate between the different problem types as on lessons 14-16 problems were only represented with words. Lastly, maintenance lessons began on lesson 17 and students were having more independent practice problems rather than demonstration or guided practice problems.

CRA-SIM instruction was implemented through implementation of five different parts being advance organizer, demonstration, guided practice, independent practice, and post organizer. The advance organizer allowed for a preview of the lesson. Demonstration provided explicit examples of problems that the teachers demonstrated to the students. This was modeled through thinking aloud and with physical objects. Teachers would elicit responses from students during demonstration. Students began problem solving alongside the teacher during the guided practice part. As a group, the students would lead the teacher through the problem by verbally saying the steps in the procedure. The teacher would provide feedback as needed. After, the independent practice part came and students began solving problems without teacher support. Teachers would provide feedback to students during this part, but would not prompt or do parts of problems for them. The lesson then ended with a post organizer which reviewed the material that was covered. As this is a CRA-SIM approach lessons one through five had students problems using base-ten blocks and their multiplication mat. Lessons six through ten had students use drawings to represent the problems on the multiplication mat. Lessons 11 through 12 focused on the SIM part of the intervention which focused on the RENAME and FAST RENAME strategy to solve multiplication with regrouping problems. Lessons 13 through 16 focused on abstract solving of problems, which is simply using common numbers and symbols to represent a math problem (ie. 7x6). Additionally, there were other operations used in the sequence of the intervention as participants needed to also discriminate between word problems by identifying the correct operation being addition, subtraction, or multiplication. Lastly, as mentioned earlier lessons 17 through 20 focused on maintenance of skills as only guided practice and independent practice was used.

In order to assess the learning within the intervention, pretest and posttest measures were done. This was done through timed probes. Students were told to answer as many problems as they could within a two minute period. Probes were scored by counting the number of correct digits below the answer line. This is to account for numbers used in adding the products together within a multiplication with regrouping problem to get your final product. Probes were also conducted during each lesson to track progress throughout the intervention. In order to be considered mastery for a lesson, students needed to score 80% accuracy.

Although both DI and CRA-SIM utilize explicit instruction, they are different especially with how they were utilized in this study. In general, DI has more oral responding, and opportunities to practice with repetition of solving problems using a procedural strategy. In the present study, DI utilized scaffolding through using grids and boxes to support regrouping and multiplying procedures throughout the problem and providing problems that were partially completed for the students to solve. As students progressed through lessons and instruction, these supports were taken away and students needed to solve the problems without any supports given. Further, as mentioned earlier, DI utilizes oral responding, so students needed to also provide oral responses on top of their written responses to solving problems.

When looking at the results, it is important to note that there were no pretest differences between the DI and CRA-SIM groups. There was a significant change for student performance across groups with a significant effect size meaning there was a difference between groups. The mean pretest and posttest scores for the DI group are 15.29 and 22. The pretest and posttest scores for the CRA-SIM group are 17 and 38.6. Although there is a difference between groups, the effect size was minimal. Participant feedback showed that 60% of the participants did not like using blocks to solve multiplication with regrouping problems. However, 100% of the students enjoyed solving the problems with drawings and 93% wanted to continue to use the RENAME strategy. These results and gains of the CRA-SIM group are similar to what has been demonstrated with other research related to CRA-SIM.

One limitation to note from this study is that this program was implemented during a summer program. Although this is typical of many schools to offer programs like this, many students do not participate in these types of programs meaning it would be worthwhile to have this study implemented throughout the school year for a more natural implementation.

Flores & Hinton (2022) The effects of a CRA-I intervention on students' number sense and understanding of addition

The purpose of the study was to determine the effectiveness of a CRA-I addition intervention on students' number sense and of addition. The study used explicit instruction through concrete-representational-abstract integrated (CRA-I) sequence. This integrates all representations from the start and then systematically removes them providing a natural scaffolding of support. The study had five second-grade students participate who had not made adequate progress in mastering single-digit addition. The participants were taught in either groups of two or one for 25 minutes per session 3 times a week during an intervention period at the school.

At the time of this study, there was no published standardized curriculum-based assessment of the target skills, therefore the researchers developed their own assessment for number sense and understanding for addition. This probe addressed the commutative property, number magnitude, strategies to solve addition problems (ie. 9 + 3 can be solved by 10 + 2) the relationship of addition and subtraction, providing missing addends, and single-digit addition equations. The administration of this probes was untimed. During baseline, students were administered this probed without instruction or feedback. During the intervention and maintenance, students received the probe prior to instruction. Addition probes were also given to the participants. Each probe contained 20 problems with sums between 10 and 20. The probes were administered before instruction and no feedback was provided to the students.

Instructional procedures had every lesson follow an explicit instruction process. Lessons started with an overview of the lesson's topic and stated the expectations. Then, the teacher described and modeled tasks. After, followed guided practice of solving problems together, which then led to independent practice. Finally, the teacher ended with reviewing the lesson and providing feedback on students' performance.

Each lesson covered various number sense and adding problems. Lessons one through three highlighted the use of concrete, representational, and abstract representations of problems using blocks, number lines, and numbers. Lessons one through three focused on solving sums to 20, solving missing addend problems, using different addends to reach the same sum, word problems and place value. Lessons four through seven used representational and abstract representations of problems and concrete representations were phased out. In addition to number lines, pictures and drawings were used to solve problems. Lesson eight featured a mnemonic strategy (FAST) to help students approach and solve problems. The remaining lessons of nine through twelve featured applying the mnemonic strategy, phasing out representational representations and used abstract representations (numbers and symbols ie. 7 + 6 = 13). All students reached mastery in the intervention for number sense and addition facts. After the intervention, all students wrote 30 correct digits per minute with correct sums. One participant maintained performance for four weeks post intervention. Two participants maintained for three weeks post intervention. Lastly, the final two participants showed maintenance for two weeks post intervention. One important limitation of this study is that this is a single-case research study, so generalizing results would need more replications of this type of study.

Hinton & Flores (2022) Concrete-representational-abstract-integrated as a tier 2 instruction to teach addition

The purpose of the present study is to add to the current research of Tier 2 math interventions on additive reasoning. The intervention designed for the study was to be used with 2^{nd} grade students. One important aspect of this study is that although the part of the reason for the intervention was to increase math fact fluency, participants needed to increase their conceptual understanding as through additive reasoning before moving into working on their math facts. The intervention was implemented into two second-grade classes using explicit instruction through, the explicit instruction of concrete-representational-abstract integrated (CRA-I) sequence.

The CRA-I sequence is a systemic and explicit approach that utilizes multiple representations. The intervention included 12 lessons for the participants to complete. The lessons were broken apart into four different phases. Phase one focused on using concrete, representational, and abstract models during instruction and problem solving. Phase two focused on using representational and abstract models during instruction and problem solving. Phase three focused on the mastery of a mnemonic device called FACTS (Focus on the problem, Another problem, Count on, Tallies, Solve the problem and check). Lastly, phase four is the use of the mnemonic strategy and abstract models during instruction and problem solving. This intervention was implemented across two years with two different groups of second grade students. The first implementation was with a group of five second grade students. Data was collected on the students before implementation of the intervention, during the intervention, and after the intervention. Across all assessments for the intervention, the assessments measured knowledge of number magnitude, use of mental strategies, relationship between addition and subtraction, and addition. Prior to the intervention, the five students had pre-intervention scores of 59%, 17%, 27% 49% and 41%. After completing the intervention, the five participants showed 100% accuracy across two consecutive assessments. Additionally, maintenance probes were conducted and the range of their performance was between 89% and 94%. Lastly, timed addition tests were given to monitor fact fluency progress for the participants. Pre-intervention scores were in the range of 16-24 correct digits with only one correct sum written majority of the time. Post intervention, the participants wrote 30 correct digits and scored 100% with their sums. Maintenance probes were conducted four weeks later and their results were the same. The same intervention was ran the following year for an entire classroom and compared to another classroom that utilized usual instruction and interventions. The results for the experimental classroom mirrored the results of the original five participants and the experimental classroom outperformed the control classroom.

A limitation of this study is that the sample size for this study is relatively small. Although, the results of were very positive and demonstrate that CRA-I is an effective model for addition interventions the results are hard to generalize to a larger population. However, it should be noted that CRA has been used in many studies and has shown effective results, similar to this study. Additionally, additional research would be beneficial to other mathematics concepts outside of additive reasoning.

Chapter 2 provided a literature review focusing on math interventions that included word problem or problem solving interventions, math fact fluency interventions, and interventions that utilized the concrete-representational-abstract sequence. The content was summarized so that the three different math interventions content was separated into its own respective sections. This was intentional in order to keep information organized. However, chapter three will begin to answer the research question “What instructional methods and strategies provide successful learning outcomes for elementary students receiving tiered interventions for math?” This will be done by splitting chapter three into three different sections. These sections are necessary to talk about implications for each tier of instruction. Each section will include implications for fact fluency instruction, word problem instruction, and the CRA sequence.

Chapter III: Results and Conclusion

The following chapter will provide implications for practice, needs for future research, and a conclusion to the paper. The chapter will begin with providing implications for instruction for each tier of instruction in order to answer the research question of this paper. The chapter will be broken initially separated into three different sections. These sections will each contain implications for practice at the Tier 1, Tier 2, and Tier 3 levels of instruction. As mentioned, Tier 1 instruction is core instruction that takes place in the general education classroom. Tier 2 instruction is small group instruction for students with math difficulties. In general, Tier 2 instruction meets a few times a week with generally four to eight students for usually no more than 30 minutes per session. Lastly, Tier 3 instruction is the most intensive intervention. These interventions are in most cases made up of students in special education. In some cases, Tier 3 interventions replace a Tier 1 intervention, in which the Tier 3 intervention would meet in most cases daily and for more than 30 minutes per meeting. However, if the Tier 3 intervention is not replacing a Tier 1 intervention, it may look very similar to a Tier 2 intervention differing in methods or strategies being utilized by educators. Additionally, Tier 3 groups are in most cases no larger than four.

Within each section for each tier of instruction will be implications for instruction on the studies that were reviewed during chapter two. The studies reviewed focused on evidence-based practices for fact fluency instruction, word problem instruction, and the concrete-representational-abstract (CRA) sequence. In addition, general implications will be made for each Tier of instruction if trends were found within the studies reviewed. After the implications for practices have been completed, there will be a section for future research. This will provide information regarding gaps in the research or current needs for research in regards to fact fluency instruction, word problem instruction, or the CRA sequence.

Tier 1 Implications for Practice

The articles reviewed in this starred paper provide effective ideas and methods that can be implemented to benefit all students. The concrete-representational-abstract (CRA) sequence was shown to be an evidence based method for teaching mathematics concepts. Although the majority of the articles focused on a Tier 2 or Tier 3 implementation, Hinton and Flores (2022) provided an iteration of CRA that was implemented in a Tier 1 setting with success. The CRA sequence was modified slightly to the CRA-Integrated (CRA-I) which allowed for more flexibility between which section of the sequence would be used. Traditionally, if the lesson is focused on the concrete portion of the sequence, only concrete objects are used to solve problems. However, in CRA-I allowed for multiple sections of the sequence to be used within the same lesson, hence the name integrated. This integration allowed for more differentiation within a lesson. Students who caught on to the concepts quicker would be allowed to progress more quickly through the CRA sequence, whereas students who needed more practice with a specific section of the sequence would be allowed to do so.

One important note for implementation at the Tier 1 level is that the CRA-I model was used throughout multiple lessons over multiple days. Hinton and Flores (2022) used the concrete and representational portions of the sequence for six lessons. The other CRA studies also implemented one section of the CRA sequence across multiple lessons. Educators that choose to use CRA-I in the Tier 1 setting should aim to use the CRA sequence across multiple days or even weeks and not for just one activity or day.

The articles reviewed for math fact fluency instruction provide useful strategies and methods to be used in the classroom at the Tier 1 level. At the Tier 1 level, instruction or practice should be individualized to the student. Although educators at the Tier 1 level are often teaching to standards for a state assessment, when instruction is individualized through identifying target problems, students are able to make meaningful growth by mastering previously unmastered multiplication facts. This can be done in a couple of ways. This can be done by using a placement test like seen in Rocket Math multiplication (Rave & Golightly, 2014). Additionally, this can be completed by using a computer-aided program that could be used on an iPad or Chromebook that is able to determine the students' performance and level the problems presented (Berrett & Carter, 2018). Another benefit of using technology is that response time is much faster than a paper and pencil method (Musti-Rao & Plati, 2015). With using technology students will be getting more opportunities to practice math facts. Students also prefer practicing math facts through a device compared to paper and pencil methods (Musti-Rao & Plati, 2015). Another implication for practice at the Tier 1 level of instruction is that rewards and goals should be thought through. Student success should be measured on relative growth, not the standard. That is not to say grades can't be given based on the standard, but if rewards or incentives are used they should be rewarded based on growth. Group performance rewards and individual performance rewards both show positive impacts for student growth specifically for multiplication facts (Gross et al., 2015). A meaningful and practical way to implement individualized growth goals is to utilize a rolling median which was also used by Gross et al., 2015. A rolling median is taking a student's last three scores on probes and utilizing the median from those three scores for a median that will then be used as a performance goal. Utilizing a performance goal like this, rather than the standard allows students to make smaller but still meaningful steps towards that final goal.

Although none of the studies reviewed focused explicitly at the Tier 1 level there are still implications that can be applied to the Tier 1 level. When conducting word problem solving instruction it is important to consider pre-requisite skills needed for word problem solving. Of the schema-based instruction (SBI) interventions for word problem solving, three out of the four studies reviewed had pre-requisites for students to be eligible for the study which of were Jitendra et al. (2013), Flores et al. (2016), and Alghamdi et al. (2020). If computational skills are not fluent in students, there is reason to believe that students will then also struggle with problem solving as it requires computation. Even though it was not explicitly studied, the researchers conducting these studies determined that pre-requisite skills were extremely important for problem solving instruction and important for determining effectiveness. Therefore, educators should also take that same consideration with their instruction. Educators should consider ensuring students have the pre-requisite computational skills and reading skills prior to teaching problem solving. Applying the CRA sequence to aid in computation in problem solving was used by Flores et al. (2016) and proved to help with problem solving skills.

Mnemonic devices should also be implemented in the Tier 1 level of instruction. A mnemonic device is a great tool to support students in the math classroom as it provides an acronym, like FAST, to aid in remembering the procedural steps that are needed to solve a math problem (Miller et al., 2011). Mnemonic devices were used in many of the CRA sequencing and SBI interventions at both the Tier 2 and Tier 3 level when analyzing the articles reviewed. The mnemonic device would provide a valuable scaffold to all students at the Tier 1 level as it would aid in remembering the procedural steps to solve a problem.

Tier 2 Implications for Practice

When looking at fact fluency instruction at the Tier 2 level there are options that can be considered for use in the general education setting through small group instruction or through cross-age peer tutoring. If a fact fluency intervention is used at the Tier 1 are individualized the data collected can then be applied to a Tier 2 intervention for further practice. When an intervention is individualized students have target math facts and practice target math facts in sets until mastery, like that is seen in an intervention like Rocket Math Multiplication. All interventions utilized at the Tier 1 level, such as computer aided programs on a Chromebook or iPad or a math facts program like Rocket Multiplication can be used to in Tier 2 interventions. A math fact intervention program like Rocket Multiplication has showed when implemented correctly significantly increases student's math fact fluency regardless if they have math difficulties or not (Rave & Golightly, 2014). Further, programs on technology such as Timez Attack produce similar results for students regardless if they have math difficulties or not (Berrett & Carter, 2018). Although neither of these studies were explicitly conducted at the Tier 1 instruction level, Musti-Rao & Plati (2015) conducted an iPad intervention and a math fact intervention program using Detect-Practice-Repair at the Tier 2 level and was able to produce improved results in students' math fact fluency. It should be noted that students preferred and showed the most growth in terms of digits correct per minute in the iPad intervention (Musti-Rao & Plati, 2015). This was due to quicker response times on the iPad compared to a paper and pencil responding method. The overall benefit of a Tier 2 intervention is the intervention takes place in a small group setting, so the students have more opportunities for corrective feedback or instruction from an educator.

Computer programs and explicit intervention programs are not the only methods that can be utilized by educators. Educators can utilize cross-age peer tutoring to also improve fact fluency. Having higher grade students such as 5th graders tutor younger grade students such as 4th or 3rd in math facts has shown to increase students' math fact fluency (Greene et al., 2018). This allows for a unique collaboration with students across grade levels to aid in each other's learning. Additionally, although not measured in the study, the students conducting the intervention would be providing an act of service which is a great social skill. One thing to keep in mind is that an intervention like this needs to be very structured and requires a lot of pre-intervention work. Educators would need to provide pre-testing to students to determine which facts need to be practiced (Greene et al., 2018). Additionally, the students who would do the tutoring would need some form of training in order to properly conduct the intervention with the students (Green et al., 2018).

Like math fact fluency, the CRA sequence has a lot of ways to be adapted at the Tier 2 level. Just like at the Tier 1 level of instruction, CRA-I is an effective way to implement the CRA sequence (Hinton & Flores, 2022; Flores & Hinton, 2022). Similarly, with Tier 2 interventions generally meeting only a few times throughout the week, CRA-I provides great flexibility and differentiation. Educators can speed along the sequence if students are progressing or go through the sequence regularly as intended. When implementing a CRA-I intervention, it is important to include a mnemonic device to aid in supporting students solving problems after physical representations and drawing representations have been dismissed (Hinton & Flores, 2022; Flores & Hinton 2022). The mnemonic device will provide students with a word that will remind them of the procedure needed to solve a problem by using an acronym (Miller et al., 2011).

Lastly, problem solving interventions at the Tier 2 level heavily utilized SBI. SBI gave students instruction on different types of problem types that they would encounter. For example, when giving SBI on addition and subtraction problems, the educator could give instruction on one specific schema type being the “change.” With the “change” schema, word problems will have specific language used in the word problem that indicates that problem type along with a specific equation that students use to plug in information to solve the problem. This can be done through an intervention program that utilizes an SBI, like Pirate Math as it was shown that it increases student word problem performance (Powell et al., 2022). Additionally, this could be utilized through an educator created intervention program based on SBI as it out performed a standards based intervention curriculum in problem solving (Jitendra et al., 2013). An important note is when teaching the schema or word problem type is to teach the problem identification and equation inputting independent of the computation needed to solve the word problem. This allows for students to master the schema and not be overwhelmed with having to first figure out the schema, then put the information into an equation, and then solve. Similarly, if students do not have the pre-requisite skills of computation needed for word problem solving, educators should consider using supports to aid in students’ problem solving skills. Jitendra et al. (2013) had pre-requisites for students to be eligible to participate in their study for having computation skills. This pre-requisite skill should be taken into account by educators as if students are not fluent in their computational skills, there is little reason that the same student will be successful in problem solving. Flores et al. (2016) had success combining the CRA sequence and SBI to teach problem solving, so educators may turn to multiple representations to aid in problems solving if students struggle with computation.

Whether it is SBI or utilizing the CRA sequence, educators should also consider utilizing a mnemonic device in combination with either strategy. Powell et al. (2022) and Alghamdi et al. (2020) utilized a mnemonic to support students with problem solving using SBI. Additionally, Flores & Hinton (2022), Hinton & Flores (2022), Flores et al. (2019), Flores & Franklin (2014) all used a mnemonic device with the CRA sequence when transitioning to the abstract step within the sequence. Essentially, a cognitive strategy such as a mnemonic device is a great support to aid students with remembering procedural steps when solving any type of problem, especially with SBI and the CRA sequence at the Tier 2 level.

Tier 3 Implications for Practice

The CRA sequence has been shown to provide growth and positive math outcomes for students when implemented correctly. Educators utilizing the CRA sequence at the Tier 3 level should implement only one representation at a time. With Tier 3 interventions being the most intensive interventions, and having students who have the highest needs and difficulties in regards to math learning, implementing one sequence at a time will be beneficial to not cognitively overloading students. Flores et al. (2019) and Flores and Franklin (2014) did this and had significant growth in their students. Additionally, they did not progress to the next part of the sequence until students had mastered the previous segment of the CRA sequence. For example, educators should not move to the representational stage of the sequence until the concrete stage of the sequence has been mastered by the students.

In addition, like at the Tier 2 level, utilizing mnemonic devices provided positive outcomes for Tier 3 interventions. Mnemonic devices are a great tool that aid in problem solving and aiding in remembering procedural steps. Flores et al. (2019) and Flores and Franklin (2014) utilized mnemonic devices for both of their studies when students moved from the representational stage to the abstract stage of the CRA sequence. When utilizing a mnemonic device educators should take a full lesson to properly implement and teach the mnemonic device. This will allow for the students to learn how to properly use the mnemonic device rather than seeing the strategy as a burden or nuisance.

Similarly to the CRA sequence being more structured at the Tier 3 level, the same follows with fact fluency instruction. Tier 3 interventions for fact fluency should utilize direct instruction to provide modeling of math facts for students Skarr et al. (2014). Additionally, it is important when educators model math facts that the entire fact is stated, not just the answer. The same goes when students are producing math facts. Students should say the entire math fact and not just the answer. Stating the fact out loud helps students better learn the facts as they are stating the entire fact out loud rather than just an answer which better helps them recall the answer later. To maximize the effects of direct instruction with math fact fluency, educators should also identify target or unmastered math facts to use during direct instruction. Skarr et al. (2014) utilized stacks of 15 flashcards mixed with eight mastered and seven unmastered math facts during direct instruction. This provides maintenance of already mastered facts, but provides unmastered fact instruction. Additionally, although not explicitly stated in this study, students should be less likely to get frustrated during instruction with mastered and unmastered facts due to students feeling successful when answering questions they know they answer to and not continually producing incorrect responses to the unmastered math facts.

Although direct instruction provides great modeling for students, it can be adapted from curriculums like Rocket Multiplication. Rave and Golightly (2014) demonstrated that Rocket Multiplication can be utilized as a Tier 1 intervention. However, in their study, the interventionist took a role as a facilitator rather than teaching all the students at once. As Rocket Multiplication follows a progression through all math facts through different levels within the intervention program. Educators could utilize this as a Tier 3 intervention and provide direct instruction on target facts based on the level students are on within the intervention. This would allow educators to use an intervention program that is proven to work with students with math difficulties and further individualize the program by providing direct instruction. Word problem instruction requires just as much structure and individualization as previously mentioned methods. Firstly, Flores et al. (2016) and Alghamdi et al. (2020) required pre-requisite skills of computation for students to be eligible for their study. This was mentioned for all levels of interventions, but it is exceptionally important at the Tier 3 level that if students do not have pre-requisite skills of computation supports need to be given. Tier 3 interventions contain students with the highest math needs. If their computation skills are not fluent or mastered, any type of word problem instruction will be difficult to yield positive outcomes. Multiplication charts or concrete objects would be ways to provide support to students to aid in computation.

Other ways that can aid students with is combining the CRA sequence and SBI. Flores et al. (2016) did this as a Tier 3 intervention and demonstrated improved performance for students. It should be noted that students needed to have pre-requisite computational skills to participate in the study, but this would be a way for educators to embed multiple skills into one cohesive unit. Flores et al. (2016) prioritized teaching the schemas for word problems first, then moving to the CRA sequence with word problems being the only way problems were presented. This allowed students to first master the schemas of word problems prior to needing the computation to solve them. Educators should take note that if this is to be utilized, students should have mastered the schemas prior to moving into the CRA sequence. Additionally, although not explicitly stated or researched, this should not serve as initial computation instruction. Flores et al. (2016) deemed it important to have pre-requisite computation skills prior to participating in the intervention meaning that computation skills are essential prior to doing problem solving and computation should be initially taught with less word problems and more rote operations.

Lastly, like seen in Tier 2 interventions, SBI on its own is still a viable strategy to be used for Tier 3 interventions. Alghamdi et al. (2020) demonstrated that SBI on its own to teach multiplication word problems. Like other word problem interventions, pre-requisite skills are important to take into account. Additionally, as was used in Alghamdi et al. (2020), schemas should be taught independently of one another before mixing all schemas together and having students differentiate between the different types. Further, Alghamdi et al. (2020) paired their SBI with a mnemonic device to aid in the problem solving process. The mnemonic reminded the students of the procedural steps needed to work through and correctly solve a word problem.

Future Research

Although this paper provides methods and implications for practice that can be utilized right away in the classroom, it is important to note gaps and needs for future research. Beginning with some of the articles used in this study are close to being ten years old. When looking at education, a lot has happened that has impacted students, with the most obvious being the recent Covid-19 pandemic. There is a worthwhile need for future research in regards to updating some of the types of interventions being used to determine if the more dated methods are still viable options that should be utilized by educators.

This paper provided implications for practice for all Tiers of instruction. However, there is a need for SBI to be determined if it would be beneficial as a Tier 1 intervention. Although, when presented to students with high math difficulties in Tier 2 and Tier 3 interventions, there is a need to determine effectiveness of SBI when presented as a Tier 1 intervention with a large group of students.

Lastly, there is a need of future research that needs to have classroom teachers or special education teachers be the interventionists when studies are conducted. Some of the research articles used in this paper had the researchers conduct the intervention. This would have students come to their campus, empty classrooms, or outside of school hours in order to conduct the intervention. In the end, teachers in schools are going to be the ones delivering instruction, so it is worthwhile to have these same teachers provide the intervention in practical settings. Students are not always going to be able to go somewhere off school grounds or meet outside of regular school hours to receive instruction. With that, future research would benefit from having classroom teachers provide interventions in their everyday setting to help determine overall effectiveness of strategies and methods being used.

Conclusion

This paper aimed to determine evidence-based methods and strategies for fact fluency instruction, the CRA sequence, and word problem instruction through all Tiers of instruction. In doing so, a comprehensive literature review of 14 articles took place to determine overall effectiveness of these methods in order to provide implications for practice at all Tiers of instruction. Overall, there were important implications and takeaways for each Tier of instruction and each instructional method researched. Fact Fluency instruction looked much different at the Tier 1 level than it did at the Tier 2 and Tier 3 level. Tier 1 fact fluency instruction focused more on the educator being a facilitator of the intervention whereas the more intensive the intervention the more direct instruction and modeling was needed to be used. This was similar strategies were utilized for the CRA sequence. Tier 1 and Tier 2 interventions utilized the CRA-integrated sequence which allotted more differentiation for instruction. Students were able to move between multiple representations within the same lesson. Whereas for Tier 3 interventions the CRA sequence was more structured and students needed to master a stage within the sequence before moving on the next stage of the sequence. Lastly, word problem instruction utilizing SBI was greatly successful for Tier 2 and Tier 3 interventions when students had pre-requisite skills of computation. If students are not demonstrating fluency with their computation, word problem instruction should wait or supports like a multiplication chart should be used. Although there were no studies reviewed at the Tier 1 level for SBI, educators should note their students' computation skills to inform their word problem instruction. Additionally, some of the articles used were close to ten years old which provides results that are dated, especially when education is working through the ramifications of the Covid-19 pandemic. However, every implication for practice that is provided within this paper provides a landing point for educators for implementing evidence-based practices into their classroom.

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