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Math Fact Fluency Instruction

Kelsey Nickel

Northwestern College

A Literature Review Presented

in Partial Fulfillment of the Requirements

For the Degree of Master of Education

Dr. Theresa Pedersen

Abstract

This literature review investigates the purpose and importance of math facts instruction at the elementary level. Being able to know basic math facts both fluently and accurately is the foundation of mathematics education. There has been research showing the lack of math facts knowledge for the students in the United States compared to their peers in other countries. Math curriculum does not focus on math facts instruction enough to achieve mastery without the use of supplemental strategies. There has been research done on the strategies to study the effectiveness. These strategies include rote memorization strategies, computer assisted instruction, educational games, and manipulatives.

Keywords: math facts, fluency, intervention strategies

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Math Facts Fluency Instruction

In elementary school, a strong foundation in reading and mathematics is key for future successes. In the subject area of mathematics, math facts are an important building block for both teachers and students to build upon in the later elementary grades. The National Mathematics Advisory Panel reports that the nationwide proficiency scores have improved, but math proficiency continues to decrease as students move from grade to grade. (Berrett & Carter, 2018) Math fluency is the foundation of more difficult and abstract math concepts that are introduced in later grades.

Hawkins, Collins, Hernan, & Flowers (2017) define fluency as being able to locate an answer to a problem both quickly and effortlessly. This is achieved when the answer is already memorized or when the student knows how to use an efficient strategy to calculate the answer. Elementary mathematics curriculum has been critiqued for not providing enough supplemental math facts instruction. The extent to which math materials focus on learning math facts can vary, but teachers can supplement with effective strategies to help build the students' overall math fact fluency. (Hawkins et al., 2017) Strategies and interventions can help teachers provide effective and efficient activities for their students to build upon their math fact fluency.

It is important to have a foundation of strong math facts fluency to better prepare students for complex problems. Many students that are not proficient in more advanced mathematical concepts lack the fluency that is needed to solve these problems. (Burns, Ysseydyke, Nelson, & Kanive, 2015) The problem is finding the most effective and efficient strategies to help students reach mastery with their math facts. Students need to be motivated and engaged in their learning for this process to be truly effective. (Spangenberg & Roberts, 2020) Denham (2013) says that if students do not develop and maintain math facts in the early elementary grades, then they

typically struggle with the math concepts that are introduced in the later grades. The research by Denham (2013) stressed the importance of having math facts be fluent to help students learn harder math concepts. There are numerous strategies that can help students be motivated and engaged to learn their math facts quickly and accurately. These strategies include traditional rote memorization strategies such as flashcards, technology and digital tools, educational math games, and the use of educational tools, such as manipulatives.

This literature review focuses on the importance of teaching basic math facts and the long-term effects this has on learning math. There are many interventions and instructional strategies that can be used in addition to the math curriculum that is used daily in the classroom. There was research done by Mononen & Aunio (2016) and Martin et al., (2019) on the effectiveness that these strategies have on the fluency of math facts. Some of these strategies include basic rote memorization techniques such as flashcards, using technology and digital tools, playing math games, and using educational tools such as manipulatives. The research also showed effects these intervention techniques had on students both in the short-term and in the long-term of their education.

Sources obtained from DeWitt Library at Northwestern College included both peer-reviewed and scholarly articles. Most of the articles were published in the last ten years. This review attempts to find out why is it important to learn math facts and what the most effective strategies are to help students reach fluency with their math facts. There has been more research done in reading fluency compared to math fluency, however, there are many correlations between the two content areas. (Wise, et al., 2010)

Review of the Literature

Background of Mathematics Education

Mathematics and reading are at the foundation of curriculum in the elementary school grades. However, math facts fluency might not be the focus of the instruction. Students need to be taught math facts as a part of their early education. (Denham, 2013) Research has shown that the United States has a history of performing weaker than other countries on standardized tests, especially in the content area of mathematics. (Rave & Golightly, 2014) “Since the 1960’s international comparative studies have consistently demonstrated that students in the USA lag behind students in other developed countries in mathematics performance.” (Ma & Ma, 2014) Researchers have been conducting studies, especially in the last decade to come up with solutions as to why American students are continuing to perform lower than their international peers on mathematics standardized tests. (Parkhurst, et al.; Rave & Golightly, 2014; Ma & Ma, 2014)

One of the overall themes in the research was the importance of teaching math fact fluency at the elementary level. Poncy, Duhon, Lee, & Key (2010) say that an important instructional piece to most mathematics curriculum is the ability to give students opportunities for repeated practice on their math facts. Repeated practice of math facts is often labeled as math fact fluency. Fluency is the ability to recall an answer to a math problem both accurately and quickly. (Musti-Rao & Plati, 2015) Research conducted by McTiernan, Holloway, Healy, & Hogan (2016) showed that students need the foundation of math fact fluency to help and support them with more difficult math tasks for their future. In this study, the researchers found that second grade students’ fluency scores of one digit math problems significantly correlated with their score on a mathematical competency assessment. Having fluency with basic math facts is

important to complete more difficult mathematics problems in the future. (Musti- Rao, Lynch, & Plati, 2015)

Basic math facts that include addition, subtraction, multiplication, and division are the basis of other more complex mathematical tasks. By being fluent and accurate with math facts, it has been shown to help better prepare students for these concepts. (Liu, Kallai, Schunn, & Fiez, (2015) “Being secure with important mathematical procedures gives students increased power to tackle more complicated mathematics at a more conceptual level, since automating skills frees up mental capacity for being creative.” (Foster, 2018) Similar to decoding skills being the foundational skill for literacy, math facts are the foundation for the area of mathematics. It has been proven that having math facts automatic, it allows students to focus more on the problem-solving aspect of learning concepts in math. One of the primary benefits of getting math facts to being automatic is being able to reduce the working memory load. (Liu et al., 2015)

Even with the research that has been conducted by multiple researchers stating how important math facts fluency is for elementary school students, math curriculum that is being used in classrooms do not allow the most effective instruction for basic math facts. (Musti-Rao, Lynch, & Plati, 2015; Berrett & Carter, 2018) There is an overall understanding that fluency is an important skill for elementary students to learn, but not many of the available curriculum provide enough practice for students to attain quick and effective recall of math facts. (Musti-Rao & Plati, 2015) Elementary school math curriculum, especially in the older grades, assume that students know their math facts fluently and no longer need to focus on the memorization of these facts. The focus of mathematics instruction switches to more complex math concepts in the older grades, whether students are fluent with their basic facts or not. Students that have not achieved math fact fluency are going to tend to struggle more with grasping some of these

concepts compared to their peers who have achieved fluency with their basic math facts. (Berrett & Carter, 2018) Denham (2013) states that after fourth grade, children typically transition from procedure concepts such as facts to more expressive forms of mathematics such as algebra and geometry.

Since most of the current math curriculum do not include enough instruction on basic math facts, it becomes imperative for educators to supplement with interventions and additional activities. There are multiple studies that researchers have done to see the effects they have on students learning their basic math facts. (Hawkins et al., 2017) Some of the most common and effective strategies to gain fluency are rote memorization techniques such as flashcards, using computer and digital tools, educational games, and using mathematical manipulatives and educational tools.

Students need to be motivated and engaged with what is being learned to have more success in retaining the information and committing the knowledge to their memories. Research by Hawkins et al., (2017) shows that drill and practice activities such as flashcards and many of the strategies in elementary mathematics curriculum has not shown to be as effective as computer assisted instruction. These activities also showed a decrease in engagement for students and an increase in less effective strategies such as finger counting. The same students showed an increase in math facts fluency when using computer assisted instruction.

In a similar study done by Spangenberg & Roberts (2020) showed that when students were engaged and motivated in learning mathematics, they were more successful in both math facts and difficult math concepts. Some of the reasons stated for this lack of motivation included a lack of attention, irrelevance to mathematics, and low confidence in mathematics. When students were motivated to learn math, it was shown that these students performed better on a

variety of math problems and possessed the ability to persevere even when the problems became challenging (Spangenberg & Roberts, 2020).

Rote Memorization Strategies

A strategy that is often used in elementary schools to work on gaining accuracy and fluency is rote memorization or simply just memorizing and recalling the answer. Flashcards are one of the most used rote memorization strategies. The research study conducted by Denham (2013) suggested that literature is in support of rote memorization because it helps with the basic recall of multiplication, but also cautioned that if teachers only focus entirely on memorization of facts that it may hinder the ability for students to transfer this knowledge to other mathematical concepts.

Most of the research focused on both the positives and negatives of using rote memorization strategies, such as flashcards. A focus of a research study by Burns, Ysseydyke, & Nelson (2015) looked at the number of repetitions or multiple tries it took to reach mastery of math facts. Certain numbers such as four, six, seven, and eight, when included in multiplication facts required more repetitions than facts that included a two or a three. Burns, Ysseydyke, & Nelson (2015) also concluded that students with lower math skills required significantly more repetitions than more skilled students. This research also showed that the number of practice attempts needed to secure mastery decreased as the grade level of the student increased. The students' grade and math skill level affected the math fact scores for the participants. When using rote memorization strategies, the main objective is to provide multiple tries and attempts for each student for each problem to acquire mastery. By being able to store basic math facts in memory, students can be more likely to develop other skills that may be necessary for solving more complex math problems including abstract mathematical concepts. (Burns, Ysseydyke, &

Nelson, 2015) Denham (2013) stresses the importance of having math facts fluent by the end of fifth grade for the students to be able to transfer their math facts into memory to use with other mathematical ideas. A common rote memorization strategy that is used in schools is flashcards. The use of flashcards has been known as an effective strategy in assisting students with getting math facts both fluently and accurately. Recent research done by Berrett and Carter (2018) showed that some other strategies, such as computer assisted instruction might be more effective due to the increased need for instructional strategies to be more motivating and interactive for students. Flashcards might not be able to provide as many opportunities to differentiate as digital tools can. The effectiveness of the flashcard strategy has not been researched in depth to see the overall efficacy of rote memorization strategies, such as flashcards. Flashcards have been a common strategy for a long time; however, its use is often unsystematic, and its effectiveness and efficacy has not been fully evaluated. (Skarr, et al., 2014) McGee, et al., (2017) states that automaticity drills that are quickly learned through rote memorization strategies does not necessarily relate to the conceptual mathematical understanding shown through standardized testing.

Computer Assisted Instruction

One of the most studied and researched strategy, especially in modern educational times, to better help and support students with gaining their math fact fluency is using computer assisted technology. In the modern and digital world, these strategies are at the forefront of the research that is being conducted as to which intervention techniques are the most effective. The students that educators are teaching today are growing up with access to technology at their fingertips, so intervention strategies that involve technology might be the most effective. Math fluency development is one area where technology can be especially useful due to the many

components that can be integrated into math technology programs. (Rich, Duhon, & Reynolds, 2017) Students can connect easily with computer-assisted instruction because it is relatable and can meet the student at their own instructional level.

Technology can also provide accommodations and modifications that students need. Crawford, Higgins, Huscroft- D'Angelo, & Hall (2016) completed a study that showed that computer assisted instruction programs have evolved from drill and practice activities to more motivating and engaging strategies that can reach different students at various levels of mathematics. Computer assisted instruction can supplement the math curriculum that teachers are already using in the classroom.

Rich, Duhon, & Reynolds (2017) suggested to educators to add both traditional paper and pencil strategies along with computer assisted intervention programs to support students of all mathematical levels to improve math fact fluency. Computer games have improved in the last decade with audio, video, and graphics that can be even more motivating and interactive for students. These games and strategies can be adapted to meet the students at their own instructional level and can include the students' likes and interests.

A research study conducted by Spangenberg & Roberts (2020) showed when students were motivated to learn mathematics, it was more likely that there was going to be an increase in participation by the students in the classroom. Students are going to be more interested in what they are learning when they are motivated. When students are interested in what they are being taught, they are more likely to apply this knowledge in all aspects of their learning. Using digital games to help students become fluent with their math facts helps students be more motivated and encouraged to continue learning and practicing their facts.

Computer assisted instruction in mathematics is mostly used for intervention and remedial situations in the classroom. Students need to receive direct instruction on math concepts and facts but also receive supplemental support on more specific topics that each individual student might be struggling with. The more motivated the students are, the more positive effects the intervention strategies are going to have.

To develop both accuracy and fluency of math facts, students need to be able to transfer their math facts knowledge into their long-term memories and be able to retrieve and use the information at the appropriate time. (Hawkins et al., 2017) Research has shown that students have shown improvements in their mathematics facts when using electronic and digital support tools. The use of these support tools is being mostly used during intervention time and not during core math instruction. In a research study conducted by Crawford, Higgins, Huscroft-D'Angelo, & Hall (2016) computer-based instruction for mathematics was found to be slightly more effective for students than traditional face-to-face instruction.

Computer games can also be more personalized and individualized for the students than some of the core instruction that is typically used in the classroom. This is extremely important for students that are in special education or gifted and talented programs. These students may require some additional modifications or accommodations that a computer game can provide easily that some core math curriculum cannot do. By adding in additional computer-based instruction strategies, this may offer teachers some needed resources that are going to help meet the needs of diverse students. (Rich, et al., 2017)

Educational Games

Educational games are shown to be effective and motivating for students to learn math facts. Games, whether digital or not, can be motivating and engaging to students and help students want to learn and practice their math facts more willingly. There is a bright future for educational games for educational and research purposes to study cognitive development in students. (Maas & Nyamsuren, 2017) Educators are not just teaching students using paper and pencil strategies anymore but trying to have more hands-on and interactive learning experiences for students, such as educational math games. Games also provide students with a competitive aspect that most children enjoy and give the students a chance to succeed. Teachers can personalize the learning environment for the student by utilizing an educational game as an intervention technique or instructional strategy. Musti-Rao, Plati, & Lynch (2015) states that if the technology and digital tools are being used skillfully and systematically in the classroom, there is going to be an increase in the students' motivation to learn mathematics.

Motivation is key to helping students want to learn and to be able to take what they are learning and being able to transfer the information to memory. To reach fluency with math facts, students need to be motivated to get this knowledge into long term memories which helps students work on more difficult math concepts. Research done by Killi, Ketamo, Kowisto, & Finn (2014) showed that educational games need to be designed with the student in mind with including competitive and motivational components. The difficulty level can be adjusted to better serve the individual student at their instructional level. Motivation can be an important aspect of learning which can be influenced by the difficulty of the educational game. (Vanbecelaere, et al., 2020) Learning can become even more interactive and fun for students when they are able to combine playing a game with technology and be successful.

Today's students learn and view the world differently than students did even a decade ago which leads to the instructional strategies that are now being used in the classroom. "They prefer play over work, fantasy over reality, immediate payoff over patience, active learning over passive learning, and working in concert with their peers, and they view technology as their friend." (Denham, 2013) Students are also familiar and comfortable with games and game-like elements in various parts of their life and transitioning this to their education is a natural progression. Most students enjoy the competitive nature that games have included. By adding in educational elements, it is going to motivate the students to learn their math facts. In a research study conducted by Rai & Beck (2012) it showed it is more likely that games will be more effective if the game characteristics such as the setting and roles of the player overlap with specific instructional goals. By adding in these known and familiar elements to an educational game, students became more interested and engaged in what they were learning which led to students learning their math facts more effectively.

Manipulatives and Educational Tools

Another common instructional strategy that educators use in their instruction of basic math facts are manipulatives and other educational mathematical tools. Students need to know and understand the purpose and use of these mathematical manipulatives for them to be useful to the students' mathematics education. Different manipulatives serve different purposes at different times for different grade levels of students. These purposes need to be explained in detail to both students and teachers to match the educational tool to the educational purpose. (Adendorff, Mntunjani, & Slyepu, 2018) In a research study by Adendorff, Mntunjani, & Slyepu (2018) showed that working with concrete materials and manipulatives helped students be able to decompose complicated concepts to the students' current level of understanding and improved

the overall performance on mathematical tasks. Crawford, et al., (2016) showed that students with lower math skills showed a greater need and attachment towards educational tools and the higher math skilled students relied on these educational tools less.

Students are also shown and taught how to use various instructional mathematical tools such as calculators to help promote fluency and automaticity of basic math facts. These tools have mixed reviews on whether they help or hinder the understanding of math facts for students. Some students can be too reliant and attached to these tools that it hinders them being able to take these math facts into their working memory. The goal is to be able to transfer math facts their long-term memories and research is mixed whether educational tools truly help with this goal.

A research study done by Crawford, et al., (2016) showed mathematics tools being evaluated to see which were the most effective for students and which tools were preferred by the students to assist them with their mathematics. Students were given access to a wide array of electronic mathematical tools and the findings showed that the calculator had an overall negative effect on the students' overall math score. In contrast, being able to use the notepad function on a computer or tablet, showed a positive impact on the students' scores. The authors find that even though the calculator showed a negative impact on the test scores, it was still the most popular tool chosen by the students. The calculator is shown to take more time to use to solve a math problem as compared to taking a fact from a student's memory and being able to correctly answer the problem.

Gaps in the Literature

There are some gaps in the literature focusing on using technology over traditional paper and pencil strategies. Typically, the older articles discuss more of the paper and pencil strategies

which lend themselves to using more rote memorization strategies and the current articles lend themselves more to the use of technology and digital tools. Researchers and educators are not in agreement to which instructional strategies and intervention techniques are the most effective in teaching student's basic math facts fluency. "The value of students being able to access math facts in a timely manner is well established; however, approaches differ on how this is attained." (McGee, et al., 2017) Everyone agrees on the importance of teaching students basic math facts and getting the students fluent, however, there are many ways to achieve this goal.

Another gap in the literature is the lack of research for students with various backgrounds which include race and socioeconomic status. Most of the studies that focus on the importance of math facts fluency include middle-class white students. A research study done by Demir, Prado, & Booth (2015) looked at parents' socioeconomic status and the relationship this has on the students' arithmetic skills and the automaticity of basic math facts. It was shown that children with disadvantaged socioeconomic backgrounds were less likely to develop both mathematics and reading proficiency and were more likely to have a learning disability than their peers with higher socioeconomic status. (Demir, et al., 2015) There needs to more representation in the research in showing different groups of students and their ability to improve their basic math facts fluency.

Conclusion

Quality math fact education is needed for students to thrive in the future. Math facts are an important foundational skill that all students need to learn in elementary school. In the past, the United States has been behind peers in other countries in mathematics education. There has been more recent research done with effective and efficient strategies that can be used in the classroom to better assist students to gain math fact fluency. Adding in technology and digital

tools into mathematics instruction adds motivation and more interactive activities to the math curriculum. There are numerous opportunities for future research in math fact fluency. One of the areas is the maintenance aspect of keeping the fluency in the students' memory. There has been research done on strategies that need to be completed to maintain the ability to answer a math fact both fluently and accurately.

Collectively, educators understand the importance of not only achieving math fact fluency, but also the ability of keeping it throughout their education. More research needs to be conducted on just how much maintenance is needed. Since fluency is a key building block to success with other math concepts, students need to maintain the automaticity of facts to better support them in their mathematics development. "Since basic academic skills are often needed to learn and master more advanced skills, the goal should be to remedy these deficits as quickly as possible so that students can experience more success on current and future academic objectives." (Parkhurst, et al., n.d.)

Overall, the main theme of future research should be the overall inclusivity of the participants in the studies. More intensive studies need to be done with various ethnic and socioeconomic backgrounds of students. Not a lot of the research studies include the wide array of students that are now represented in our modern school system. One strategy is not going to be a one size fits all for every student and more research needs to be completed to reach every student. More in-depth research is needed to pinpoint what is needed to make each student successful in learning their math facts.

Mathematics is important to every students' overall education and effective strategies are needed to maintain math facts to help with other mathematical concepts. Math facts lay the groundwork for future success in mathematics. Students need to be motivated and want to learn.

Effective strategies help teachers create a more engaging environment in the mathematics classroom. Maintenance is attained with math facts when the students are automatic with their answers and can take their facts into their working memory. The goal is for students to not have to work for the answer but already have the answer available to them using their mathematical knowledge. Math facts are the building blocks for a successful mathematics education.

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