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The Importance Of Math Fact Automaticity

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THE IMPORTANCE OF MATH FACT AUTOMATICITY

By

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DEDICATION

To my past teachers who inspired me to love learning.

Also, to all my future and past students who will forever hold a special place in my heart.

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CHAPTER ONE

Introduction

The art and science behind teaching math to elementary aged students can be magical. When students understand the why behind a basic procedure or when they light up after successfully solving a difficult problem is remarkable. However, these feelings are not always present in the math classroom. This school subject can be filled with frustration and challenges. As students progress through grade school, the amount they rely upon the automaticity of basic facts increases exponentially. The problems they solve no longer test if they know a fact, but the multiple facts they need to recall to solve a complicated problem. Those who have their basic facts memorized do significantly better in certain math units while their peers may struggle. What we need as educators are resources and tools to encourage the learning and retention of basic math facts in our classrooms. This leads to my research question; *What methods are most effective for teachers to implement with their striving learners to allow them the opportunity to retain their basic math facts?*

Investigating this question has the potential to help students in my classroom and school immensely. Learning the research and strategies to support fact automaticity will help me support my learners for years to come. This is a skill that is not going away; students need a basic understanding and the ability to quickly access math facts. Without this skill, they will continually run into frustration as they progress through higher level math courses. Baker and Cuevas state, “There are studies that have found math fact automaticity to be a predictor of performance on general mathematics tests” (2018, p.3). My hope is through my research I am able to find different platforms to assist my learners

in the fact retention process. I will then share my findings with colleagues, so they, too, can assist their students.

In the remaining pages of this chapter I will go into detail about my math journey to this point. This will include how I learned my basic facts in grade school; I was exposed to a variety of programs and strategies. I will also discuss the memorization strategies that were used during my student teaching semester and what my current teaching position utilizes. Then I will dive into the rationale and importance for the retention of basic math facts. This is a topic I am passionate about, as I run into issues pertaining to it almost daily. Lastly, I will summarize the chapter and include the most pertinent information moving forward with the remaining chapters of my paper.

Personal Math Journey

When I look back on my math education in elementary school, I have a variety of memories. I can distinctly remember negative feelings about the subject in third grade. During this hour of math each day my teacher would cold call names for answers. I recall being anxious and constantly checking the time to see when math would be over. Thankfully, besides this one difficult year of grade school, I loved math. I always considered myself an average math student until middle school. Then a teacher placed me on the track for advanced classes and I worked hard to do well. The topics did not necessarily come easily, but I was determined to succeed. Math has since become one of my favorite subjects to teach and study outside of the classroom.

When it comes specifically to math fact automaticity, I participated in many different memorization activities. In 3rd grade my school used a program called *Tools for Success* (Tools for Success: Math Facts, 2021). This curriculum had five different

operation categories - addition, subtraction, multiplication, division and mixed facts. Within each operation there were 26 levels, A was the most basic and Z was the most complicated. To begin this process, my peers and I took an entry level test for each operation and were then placed at the appropriate letter level. Each level had a certain amount of problems and we would orally go through and say the answers to the basic facts. We had one minute to complete as many as possible. If we achieved a certain number of correct problems, we were able to move to the next level. If we struggled and received a specific amount incorrect, we would repeat the level. The goal was to reach level Z and then graduate onto the next operation. I did quite well with this curriculum and made it through all five operation categories during that school year.

In 4th grade, my teacher did not use *Tools for Success*. Instead, we participated in weekly timed tests for addition and subtraction for the first half of the year and then multiplication and division for the second half. We tracked our progress over time and worked toward various goals that included prizes. Once again, I did well on this system and had no issues reaching the various milestones. This year I was also introduced to a game called “Flash.” To play this game, we would sit on our desks and one by one rote count by various numbers. We started counting by ones and stopped at ten, we would go through this rotation three times. Our goal was to complete it in one minute. If we were successful, we would move on to counting by twos and so forth. It was easy at first, but as the numbers increased, it became more difficult for my class. One strategy my teacher used was a song for the sevens to the tune of *Happy Birthday.* To this day, I still have it memorized and use it when multiplying numbers by seven.

Besides the few situations described above, I do not remember any other fact retention strategies during elementary school. I am sure my teachers did inexplicit games and activities that helped my classmates and me to master our facts. By fifth grade I remember knowing my facts well and never having issues with them. I excelled through math and currently use the memorization strategies I learned as a child to solve math problems.

For my semester of student teaching I had the unique opportunity to leave Minnesota. I became involved with a program called *Chicago Semester,* which allowed me to live and student teach in Chicago, Illinois for four months prior to my college graduation. I taught in a second grade classroom, which consisted of 32 students. As a whole, my class spoke sixteen languages and not one spoke English as their home language. As you can tell, it was an extremely diverse population and very different from other practicum experiences I had in college.

During this placement I had little say in the curriculum and systems that were taught, but instead immersed myself in the procedures my cooperating teacher instructed. With that being said, I conducted timed fact tests with my students. We concentrated on addition during the semester I student taught and the class moved onto subtraction after I left. Each week, the students would complete a timed test. I would then grade their tests, hand them back and students completed a bar graph to show their growth from week to week. I remember this process going well for most students, but the students receiving Special Education Services struggled immensely. They did show growth, but it was less than their peers.

After student teaching I returned to Minnesota and began teaching fourth grade in the Mounds View school district. I can distinctly remember one of the first all staff meetings I attended during workshop week. Our math coach did a professional development session on math facts. She explained the negative effects of timed tests and how teachers at my school should no longer have their students complete them. I am now in my fifth year of teaching in Mounds View and have never given a timed test. My fellow coworkers and I do very little in class to encourage math fact retention. We encourage families to work on facts outside of school, but their performance overall rarely improves. Unfortunately, I have seen the effects of not being intentional in the teaching of math facts and that is what is fueling my passion for this subject.

Rationale & Importance

This topic is important to me because as a teacher I see many students understand how to follow the multiple steps in a complicated problem, yet they are unable to be successful because of a basic math fact error. The automaticity of multiplication facts can be utilized in a variety of mathematical situations. Division, word problems and fractions are just a few that are greatly influenced by a students' retention of their multiplication facts. Since this is such an important skill in higher levels of math, it is crucial that students have a solid mastery of their basic facts in order to be successful. Boaler argues, "Number sense is the foundation for all higher-level mathematics" (2015, p.2). My colleagues and I often tell parents and students to practice these facts at home, but no progress is being made. I believe that in order to see positive change with this topic I need to give my students specific activities that will propel them forward and solidify the automaticity of basic facts.

In my classroom we have a unit on multiplication, which concentrates on the numbers 0 through 12. This unit includes lessons on prime/composite numbers, factors, multiples and arrays. These topics give a strong foundation as to what multiplication is and the components that influence it. By the end of the chapter students can figure out any single digit multiplication equation. Some may choose to draw a picture, others skip count, while others are able to recall the fact from memory. Whichever strategy the students use to solve the problem is acceptable, as long as the correct answer is found in the end.

As a class, we then go onto the next chapter, which is on the multiplication of multidigit numbers. We teach a variety of strategies, but each one requires the knowledge of basic facts. The focus is no longer on the basic fact, but instead on using basic fact knowledge to multiply multiple digits together. Students who have their facts memorized are more successful than those who do not. For example, if a student needs to know 3 x 7 to complete their lattice multiplication strategy and they need to draw out 3 groups with 7 tallies in each, by the time they figure out 3 x 7 is 21, the motivation to complete the rest of the problem is completely gone. This situation also causes some students to be inaccurate when they reach larger numbers. For instance, if a child needs to know 9 x 8 to complete a strategy known as partial products, and they need to draw a picture to identify the basic fact, there is a greater chance for errors since the numbers are so large.

I believe the root of this problem is a lack of basic fact retention strategies in schools. In our current digital world, there is less of a need to memorize information. Some schools have also gone away with timed fact tests because they cause anxiety for students. Instead of finding a different avenue for students to learn and practice their

facts, this area has been glossed over. We are left with frustrated students who continue to stumble in math due to errors in their basic math facts. Another critical factor that affects my area of focus is students with different learning disabilities. Some students are unable to retain large quantities of facts. Since this is something I am unable to change, I am hopeful to find a way to make these facts more approachable and allow them to compute these problems more efficiently.

Summary

To conclude, the subject of math has the power to be either inspiring or discouraging. A root cause for these feelings towards math in elementary school comes from the math fact automaticity process. This is an area that has been neglected in many schools as timed testing has gone away. This is resulting in frustrated students who have many barriers moving forward in other math topics. Over the years I have participated in many forms of fact memorization strategies- some good and some bad. I think it is crucial to find effective strategies for my students to focus on learning basic math facts and being able to put them into practice.

In the remaining chapters of this paper I will continue to dive into this topic of retaining math facts as I approach to answer, *What methods are most effective for teachers to implement with their striving learners to allow them the opportunity to retain their basic math facts?* In Chapter Two, I will present a literature review of different sources I analyzed related to this topic. This will include information on memorization as a whole, links between math fact retention and future math success and strategies to encourage math fact fluency. In Chapter Three, I will share details about my final project. This will include why I chose to create a website and how I hope to use it in the

future. Chapter Four will include my personal and professional reflection on my research and project related to fact automaticity.

CHAPTER TWO

Review of the Literature

Introduction

The goal of this second chapter is to examine research that has been completed relating to the automaticity and fluency of math facts. Over the years there has been a variety of studies conducted and a plethora of exploration around this fascinating topic. The guiding question for this literature review is: *What methods are most effective for teachers to implement with their striving learners to allow them the opportunity to retain their basic math facts?*

To accomplish this review, five different topics will be examined to create a full picture of this dynamic topic. First, a basic understanding of memorization will be discussed. This is a foundational piece of this topic as it will help to unveil why memorization is so important and how it begins to take shape in the human brain. Secondly, the history of fact automaticity will be analyzed. This section will be discussed through an educational lens. The learning methods seen in schools have gone through drastic changes when it comes to the use of memorization. This will be vital in understanding why math fact fluency is an untouched issue with educators today. Next, different math fact retention strategies will be analyzed. This will include positive and negative approaches that have been used in the past and present. This section will then transition into the next one, which is on the link between fact fluency and math success. This specific topic has been researched at varying levels and will help to show the importance of enforcing math fact automaticity in schools. Lastly, different conditions

that impact memory will be considered. This section will include what these conditions are and what strategies can be used to mitigate the side effects.

Memorization

Memorization is a complicated process that is the foundation behind a lot of our daily tasks. Memorization is not a stand alone skill. It spills into other areas of life and makes other tasks easier for the mind to carry out (Nasrollahi-Mouziraji, 2015). In recent years there has been a movement to de-emphasize memorization and, while the change has been positive in some aspects, it is taking a toll in others. Acknowledging the basics of memory will assist in recognizing how to improve the lack of math fact automaticity seen in schools today. More specifically, this section will look into what memorization is and how it occurs in our brains. There will also be detail about how memorization affects our everyday lives in both an academic and nonacademic setting.

Memorization includes two systems and is referred to as the Dual-Process Theory. System 1 is more automatic and encompasses unconscious thinking, compared to System 2 which is more analytical and effortful (The Derek Bok Center for Teaching and Learning, n.d.). Math fact memorization would be included in System 1. A more complicated multiple step word problem, requiring a greater depth of knowledge would be considered System 2. The Derek Bok Center goes on to say that a solid performance by System 2 requires a lot of System 1 information to work and operate in an efficient way.

Within these two systems of memorization, there are three steps when it comes to processing information. Each of these tasks play a crucial role in memorization. The first is memory encoding. Encoding is when information comes into our brains. These

memories are then encoded through the means of visual-picture, acoustic-sound, semantic-meaning or tactile-feel (McLeod, 2013). Our brains need to process the information in a way it will understand. It has been compared to changing currency when traveling or translating words into a different language. Secondly, McLeod goes on to say that storage comes into play. This process is more commonly known as short and long term memory as it refers to where, how long and how much information can be stored. Short term memory holds onto information for up to 30 seconds and can only hold onto about seven items at a time. Long term memory, on the other hand, grasps onto information for an infinite amount of time (The Derek Bok Center for Teaching and Learning, n.d.). The last processing step is memory retrieval, which includes recall and recognition. Boundless Psychology (n.d) articulates in paragraph two, "In recall, the information must be retrieved from memories. In recognition, the presentation of a familiar outside stimulus provides a cue that the information has been seen before." Each of these three information processing systems work together to create memorization and the retrieval of various memories.

The improvement of memory is possible through the use of different strategies. One more commonly used is state-dependent memory. This method allows for memories to be recalled when the initial place is focused upon (The Derek Bok Center for Teaching and Learning, n.d.). One example of this is when people are able to remember notes from a lecture when they picture where it is placed in their notebook and how it looks. Another commonly used memory aid is through the process of organizing information. This includes memorizing sequences or perhaps putting things in alphabetical order (McLeod, 2013). Another approach that falls into this category is talking about items in a

chronological order, like parts of the day or year. Most people are better able to remember things when they recall the order in which they happened, even years later.

Educators are able to utilize some of these memorization techniques to assist their students in the learning process. The biggest key is doing a hybrid approach to learning; allowing for both memorization, but also a deep understanding to take place. There is a place for each of these methods and they truly build off one another (Weinstein, 2018). Different topics require these two techniques to occur in different orders. One could argue that memorizing math facts begins with a basic understanding of what is occurring, then memorization should occur to catapult the understanding of more complicated math topics. Another teaching method that has been proven to be successful is the use of interleaving instead of blocking. Blocking refers to teaching a topic by itself in solidarity. Interleaving weaves different skills together (The Derek Bok Center for Teaching and Learning, n.d.). The spacing of information can also have a big effect on one's overall ability to recall information. We all know that cramming the day before a test is not successful in achieving long term memory. It is more useful to space information out and have constant reminders of it over time (The Derek Bok Center for Teaching and Learning, n.d.). One example of this is a daily math warm up where different skills are incorporated over time to refresh, review and sharpen the concept.

Memorization has many beneficial effects both academically and non academically. Ferlazzo argues, "[Memorization] is the fuel that sparks interest and innovation" (2020, para. 3). A high school history teacher insists his students would be unable to debate topics related to Alexander the Great if they could not remember important places, dates and events (Ferlazzo, 2020). This builds off the initial quote

shared in this section. Memorization really is the foundation for other skills and allows one to flourish in different areas. Alieh and Atefah Nasrollahi-Mouziraji argue that rote memorization should be viewed as a complementary role for understanding. This is seen when looking at English-Language Learners or even infants as they begin to develop language patterns. These two groups of people will observe and repeat language around them, which comes from memorization (Nasrollahi-Mouziraji, 2015). Research has also shown how frequent memorization improves one's ability to memorize and even increases the size of certain brain structures. Many activities we partake in are more passive for our brain, such as reading. Memorization increases the neural passageways and overall plasticity of the brain (Garlock, 2020). Having a healthy and active mind allows for tasks to be completed with ease.

Clearly memorization is a complicated process that even scientists are trying to completely understand to this day. It is an important function to understand, as memorization drives our every move and daily tasks. Certain strategies can improve overall automaticity and make one more successful in recall. Knowing this information about memorization can assist educators in how to teach math facts in a more beneficial and logical way. In the following section, the history or memorization will be discussed and how it has changed over the years in education.

History of Memorization

Memorization has been highly linked to education over the years. In the past there has been a huge emphasis on memorization across the board in different subject areas. Older generations likely memorized poetry and recited historical documents aloud (Lange, 2019). Since then these practices have been deemed poor practice and the overall

need for memorization in schools has dwindled greatly. In this section, a timeline of memorization in our education system will be discussed. There will be an emphasis on strategies and activities implemented during these varying times.

A large portion of education decades ago revolved around memorization. It would be common for students to recite math facts, literature and even famous speeches aloud in front of their class. Students were largely assessed on what they had memorized from their textbooks and lectures (Lange, 2019). Unfortunately, in the past thirty years there has been a large number of studies which show an increase in misunderstanding amongst these students (Reeder, 2002). These results show that memorization is not synonymous with mastery. Because of these findings, the specific practices mentioned previously in this paragraph are almost unheard of in schools today. There are multiple reasons why this shift has occurred and it will be discussed in the pages to follow.

One cause for this change in pedagogy is the discussion between "surface learning" and "deep learning." In order for deep learning to take place there needs to be a mix of understanding and memorization (Tan, 2014). In some cases this has created an extreme where memorization is looked down upon and is not taught at all. If it is taught the incorrect procedures are encouraged such as "cramming" which has been proven to be unsuccessful in the development of long term memory (Bosman & Van de Lint, 2019). Many believe that simple memorization is not true learning. While this may be true to some extent, the deep learning all educators want their students to achieve requires the use of automaticity as a foundation.

Also, National and State Standards in the past have traditionally been geared towards memorization. The verbs used in these statements require students to list,

identify and select. In recent years there has been a shift in the standards to require skills higher up on Bloom's Taxonomy, such as validate and reflect (Acevedo, 2016). This change allows for more understanding and application to occur. Acevedo goes on to say, the Common Core State Standards have also been more conscious about diving deeper and covering less overall topics. This also allows for a more solid understanding, instead of simply learning surface level material.

Another modification in the world of memorization and education is less of an emphasis on one text book being the sole means of instruction. This movement has been seen recently, especially in history classes. Traditionally, students would have one history textbook and that would be their vessel to learn about different topics. Instead, some history teachers are using multiple sources to gain different perspectives (Gewertz, 2012). This break in materials allows for a different kind of learning to take place besides simply recalling facts and dates. One history teacher who is immersing herself in this new practice described how much more engaged her students are on a daily basis. Instead of regurgitating facts about Rosa Parks, her class launched an investigation trying to figure out where on the bus she sat. Students had to analyze several sources, defend their opinions and share their findings (Gewertz, 2012). This kind of learning experience builds upon other life skills and takes one away from shallow memorization learning.

The memorization of math facts has also had its fair share of changes over time. At one time reciting math facts orally was common practice in front of one's peers. The use of timed tests was heavily used and is still being practiced today in some settings. Some have taken on the belief that memorizing facts is damaging to the development of general math skills and does more harm than good (Northern, 2016). There has also been

great debate about what the Common Core State Standards (CCSS) mean when they state on page 23, "By the end of Grade 3, know from memory all products of two one-digit numbers" (2021). Some argue that the terms "from memory" mean instant recall. Others believe it means the ability to calculate the answer in an efficient way (Northern, 2016). The difference in interpretation of this standard allows for differences between districts, schools and classrooms.

The topic of memorization is highly debated in schools today. Some think it is good, others think it is negative. One complaint towards memorization, is it allows for a lack of understanding to occur (Orlin, 2013). Teachers see their students can memorize math formulas, but have no idea what it means. One example of this is when students are adding multi digit numbers. They carry the one because the routine is drilled into their memory, but they have no clue why that "trick" works. Orlin states, "[Memorization] is a detour around all the action, a way of knowing without learning, of answering without understanding" (2013, para. 7). The issue educators face is deciphering what is important for their students to memorize and how a deep understanding can occur in conjunction with memorization.

To conclude, there are a plethora of reasons why memorization has fluctuated so greatly in our education system. The change in standards, textbooks and knowledge of memorization versus understanding are a few of the root causes. The overall view on memorization in classrooms is also highly debated across subject areas. Some believe there is a need, whereas others do not see the importance. Educators should strive to strike a balance between these two opposing concepts to create harmony while learning. When this occurs the mastery of math facts is more likely to occur in an organic way. In

the next section of this review, the concept of successful and unsuccessful math fact retention strategies will be debated.

Fact Retention Strategies

Throughout the years educators and researchers have looked to find strategies that encourage the automaticity of math facts. There are successful and impactful lessons, discussions and activities that truly can foster fluency in math skills. It comes down to making meaning of the numbers to create an overall well rounded math student. Through the use of technology, games and a solid fact foundation students will be more successful. In this section robust programs, which improve the memorization of math facts in a more natural way will be discussed. There will also be information on what strategies do more harm than good and should be avoided if possible.

The development of number sense occurs in very young children and continues to grow throughout grade school. The authors of McGraw Hill believe, “In general, children begin solving math facts through counting - Phase 1, progress to using reasoning strategies to derive unknown facts - Phase 2, and finally, develop mastery with their facts - Phase 3” (2019, para. 4). It is important for each mind to go through all three stages, without skipping any. If this occurs, then the basic understanding is not developed. One way to ensure a student achieves success in all phases is to introduce numbers and manipulatives at a young age. Children at age three can begin playing with chains of beads that contain ten sections of different numbers. For example one chain would have ten sections with three beads in each section, another would have ten sections with six beads. This helps children begin to count, but also recognize patterns as they skip count later on in their development (Hollis Montessori School, 2018). Not only does this

exercise give visual support, it also provides tactile input to aid in memorization more naturally.

While manipulatives are an excellent scaffold in the learning of math facts, it is important for children to understand why they are using them (Bielsker et al., 2001). This connection needs to be made explicit. This conversation also allows for students to see the transfer between a skill and a tool. Different skills and tools can be intermixed when students know the appropriate times to use them. Again, this is something that needs to be taught and not assumed all students understand.

Boaler argues, "Number sense is the foundation for all higher-level mathematics. When students fail algebra it is often because they don't have number sense (2015, p. 2). Number sense refers to the ability to break apart numbers and understand what they represent in a variety of contexts. In order to manifest this critical piece in one's mind there are a variety of activities that can be taught. One is the participation of number talks. This includes presenting a problem like 6 x 3 and having students solve this problem mentally in as many ways as possible (Boaler, 2015). The teacher then records the strategies used to gain the answer. The whole idea behind it is to show students how dynamic math can be, it is not static. It also introduces more unique math strategies to the class to possibly use in the future. This idea of mental computation is strong as well because it steers students away from pencil and paper problem solving, which can take more time. Mental computation requires teaching and can be a valuable resource for certain students (Bielsker et al., 2001).

It is argued that a premature emphasis on speed and accuracy takes away from the love and development of math. One study found that math anxiety can be seen in children

as young as five years old (Boaler, 2015). It is best to understand how one learns and then build upon that when it comes to math facts. This avoids any unnecessary discomfort around math. The Everyday Math curriculum utilizes three key strategies to accomplish this goal. First, they use interleaving. This concept includes working on a variety of topics at the same time. One example of this is a worksheet with both multiplication and division problems. Learning in this way is beneficial in other areas as well, like music. Secondly, they utilize games. Not only are games engaging, but they also allow children to progress through the phases at their own pace. Lastly, formative assessments are crucial in developing a solid math foundation. Some examples of this are an interview, where a child can discuss their work. Recording observations seen while playing a game is also a powerful form of assessment (McGraw Hill, 2019). Each of these examples of positive strategies in the classroom allow for more organic learning and memorization to take place.

Another important aspect of teaching math facts is understanding the difference between drills and practice. A drill is repetitive, whereas practice is more problem-based and requires problem solving (Williams, n.d.). Requiring students to repeatedly do drill exercises for long periods of time is not beneficial. It is recommended to do shorter drill periods focusing on specific fact families. Doing all the facts at once is overwhelming and patterns are unable to be noticed. Another helpful strategy is to go through the fact families in a logical way versus starting at zero and ending at nine (Williams, n.d.). Doing “easier” facts is helpful to gain confidence at first. It also makes sense to learn the three fact family before the six fact family, many of those numbers are similar as they build off of each other.

One way to introduce the patterns of math facts is through a lesson on Sieve of Eratosthenes (Room to Discover, n.d.). This lesson has students analyze a ten by ten, hundreds chart with the guidance of their teacher. It can be used in a variety of ways, but one common activity is to go through and skip count by numbers to see which are prime and which are composite. This process assists in finding patterns between numbers and can be very helpful in teaching addition and also rote counting with multiplication. Room to Discover (n.d.) argues, "When students have number sense, they can build *all* the math facts, rather than memorizing them one-by-one." It is crucial for educators to implement lessons and activities like the Sieve of Eratosthenes to allow this flexibility of the math mind.

One research team at Cambridge University looked at the lasting effects of cramming versus the use of mnemonic devices. A mnemonic device is a tool used to aid the memorization process (Bosman, 2015). It is commonly used to remember the order of items by noticing the letters each word begins with and then creating a phrase to match. When it comes to math facts, a helpful mnemonic device is "8 times 8 fell on the floor, pick it up and it's 64." Another common one is when multiplying by nine, you use your fingers and palms to solve a problem. It was found that through the use of mnemonic devices, the amount and quality of memorization is much higher (Bosman, 2015). "Mnemonics is more effective than rote memorization because it requires the brain to make more associations" (Bielsker et al., 2001, p. 49). These tools are helpful for students to know, but there is importance in them truly understanding before memorizing a saying.

Once students reach higher level math classes, teachers often feel they do not have time to practice math facts. There are several topics that support the understanding and fluency of math facts even in upper elementary and middle school (Room to Discover, n.d.). Some of these topics include ratios, factoring and functions. When these concepts are understood on a conceptual level instead of procedural, they complement math fact memorization very well.

Some of the more practiced routines in classrooms today, such as repetition and timed tests, are not the most effective (Boaler, 2015). We see them practiced so regularly because most math curriculums do not include strategies to help with the retention of math fact mastery. Instead, teachers are forced to rely upon old strategies they were taught in grade school, which are outdated and not best practice (Allen, Lyall, 2018). It has been shown that timed tests produce math anxiety and do not give the results teachers, parents and students want. When our brains complete different exercises, neurons create connections. When these connections are used over and over, they become stronger and skills become more natural, possibly even falling into the category of memorization. When these connections are not strengthened, they are pruned to allow for more information to be stored in our brains (Room to Discover, n.d.). This is why cramming for math fact quizzes is not effective. Repetition during one math unit is simply not enough to get these memories to stick for the long haul. The idea of timed tests is also negative as they give students an idea that thinking is not involved when computing facts (Bielsker et al., 2001). They look at it more as an instant answer, instead of understanding what the facts mean.

To conclude, learning math facts needs to take shape through a series of phases. Each step has importance for creating a deep mathematical understanding to propel scholars forward in their learning journey. Each of these phases can be accomplished through a variety of exercises, games and theories. The most important takeaway is that intentional learning needs to take place for math facts to truly be learned, memorized and eventually fluently mastered. The following section will cover the links between fact fluency and future success. More specifically, different journals and articles related to this subject will be analyzed.

Links between Fact Fluency & Success in Math

As we know, the ability to quickly retrieve math facts impacts students as they advance through different math topics and levels. The question becomes how important is the fluency of math facts and is it truly a foundational skill that affects math in upper levels? In this section different studies will be discussed and analyzed relating to this topic. Specifically, it will include information on the relationship between math fact automaticity and overall success in math.

One study tested 155 students on basic multiplication facts. They found that 13 percent were fluent. Of this same group of children only 3 percent were able to solve more complicated questions related to multiplication (Baker & Cuevas, 2018). This shows there is a strong correlation between the ability to quickly access basic facts and being successful in higher level thinking math. One reason for this connection of tasks is that by knowing basic facts, the cognitive load is much less when approaching problems (Allen-Lyall, 2018). If a child is instantly able to recall 4 x 8 is 32, they are able to use that answer to find a common denominator, for example. When students are taking time

to draw out eight circles with four tallies in each circle, by the time they discover the answer is 32 they are mentally spent without even doing the bulk of the problem.

Another study looked at the correlation between fact automaticity and proficiency on a state standardized test. They looked into grades three, four and five to see if there was a connection between these two concepts. The team found that in third grade there was not a strong correlation between a child's fact automaticity and their test scores. However, the opposite was found in grades four and five. In these two years of school, there was a link between math fact knowledge and overall test score (Brewer et al., 2017). These results allude to the idea that as math becomes more complicated, a strong foundation of math facts is helpful to be successful. To support this claim, Baker and Cuevas state, "There are studies that have found math fact automaticity to be a predictor of performance on general mathematics tests" (2018, p.3). They also argue that having a mind that is quickly able to computate numbers and find patterns amongst them is a recipe for success when it comes to thinking at higher levels. If one does not have the capability to quickly solve problems, they will likely experience difficulty later on in their educational career.

In Asian cultures, the idea of rote memorization, drill and board work, has shown itself to be effective. Math scores from students in China are higher than those in the United States when it comes to number computation (Bielsker et al., 2001). An emphasis on the automaticity of math facts in Eastern education systems results in more math fluent students throughout the years. While teachers in the states may want to copy what schools in Asia are doing to develop math experts, it may not be the best idea. Experts wonder if the strategies that are so successful in China to create fluent students are

possibly not as effective here in the United States (Bielsker et al., 2001). The cultural differences in these two locations are immense and specific pedagogy for each unique group of students needs to be considered. The basic understanding of math operations is crucial. It is the responsibility of educators to ensure this learning takes place in the most effective way for their students (Boaler, 2015).

It has been found that students may know their facts well when presented with raw fact questions. The real trouble brews when they need to apply those same facts in a different situation (Bielsker et al., 2001). In other words, there is little transfer of math facts between topics, situations or even subjects. This is problematic as the whole goal in understanding and retaining fact tables is that these numbers can be quickly drawn on as different problems arise. One way this situation can be avoided is by the teacher explaining why learning facts is so important. An explanation of when and how to use math facts is just as powerful for young minds. Students need to be taught how to transfer information; it does not happen automatically (Bielsker et al., 2001).

The information in the previous paragraphs may be discouraging for educators to read, as they are sure to have students in their midst who seem behind in the topic of math fact fluency. Baker & Cuevas argue, “Research suggests that teachers can use students’ level of prior knowledge to determine what intervention might help them reach automaticity with multiplication or other basic mathematics functions” (2018, p. 3). This is promising as it allows striving learners to make great gains and hopefully reach their peers who have a solid understanding of math facts and topics. Similar findings in a different study were also found, which showed that direct intervention with math fact understanding and memorization brings positive results. This study focused upon this

concept and found that not only did math fact retention go up, but student confidence did as well (Allen-Lyall, 2018). Students who are discouraged with their math facts will be less motivated towards all areas of math, so the idea of specific interventions having such strong results is encouraging.

To conclude, those with a solid understanding and ability to quickly access their math facts will see more success throughout their math career. Hope is not lost for students who are not yet at this point. Specific interventions and strategies can be implemented to lessen the gap. While quick recall is important, it is crucial to remember that an understanding needs to be developed as well. This next section will dive into ailments that impact memory in our schools today and how it can be combated.

Impacts to Memory

Unfortunately, there are a number of conditions and disabilities that impact one's ability to recall information. The International Dyslexia Association states, "Individuals with traumatic brain injury, deafness, oral language deficits or genetic disorders such as Down Syndrome are more likely to have weak working memory" (2020, para. 2). This then impacts the ability for these students to learn and be successful in school, especially when it comes to math. We see this at work as we look into Special Education cases and compare their academic accomplishments to their general education peers. This section will focus upon what these specific conditions are and how they impact working memory. It will also discuss how these automaticity issues can be mitigated in the school setting to a certain extent.

There are different kinds of memory. Episodic memory refers to being able to recall events and details pertaining to them. Procedural memory on the other hand

encompasses being able to complete different tasks from memory, like driving a car. Semantic memory includes educational learning, like knowing the definition of words and basic math facts (International Dyslexia Foundation, 2020). Students in classrooms with ADHD or learning disabilities most likely have trouble with their semantic memory. This causes issues in math for a variety of reasons. For one it can make copying information more difficult. Students may complete the incorrect problem and end up with the wrong answer. It also causes math fact retrieval to be much slower and more difficult math concepts to be very challenging (Baker & Cuevas, 2018).

These disabilities are very real and to some extent, there is not much that can be done to increase the memorization capabilities of these students. However, this does not mean that these children have little hope when it comes to their math career. One recommendation is that students have access to basic math facts with either a calculator or math fact chart (International Dyslexia Foundation, 2020). This helps these striving learners the opportunity to grapple with more difficult math concepts and have success. Students with memorization challenges are more likely to approach math facts with paper and pencil strategies (Baker & Cuevas, 2018). While this is fine in some developmental areas, it is not appropriate nor the most efficient in higher grade levels.

Another approach that has been successful to support math success with children experiencing memorization problems is by displaying procedures for them to refer to on occasion. One study, which looked into two 7th graders with learning disabilities, found that when the procedure they needed to complete was by their side, they could easily plug in the correct numbers and attain the right answer (Lambert, 2015). This level of support

is not needed for all learners, but on occasion such scaffolding is required. The International Dyslexia Association (2020) supports this idea as well and shares that viewing past example problems can assist students.

When it comes to memorization, there are more obvious diseases, injuries and disabilities that directly impact it. Educators, for the most part, are very accommodating to these situations in different contexts. However, there is a more "invisible" issue that can come into play as students make their way through their education careers and that is their genetics. One study done by a team at the Hammill Institute on Disabilities looked into twins and their ability to memorize, not only in a math setting, but in reading as well. It focused upon math fact fluency and decoding in reading. It was found that both of these topics, heavily based on memorization, were impacted by the genetics of the child (Hart et al., 2012). Some people have the capability to memorize more than others. This is important for educators to understand as it allows for more grace to be given. It also helps to understand why some students seem incapable of memorizing, even when successful strategies are put in place.

When instructing students to memorize, it is crucial to keep in mind different variables that impact the memorization process. Certain tools and scaffolds can easily be put into place to make all students successful. These interventions avoid unneeded frustration in students and fosters a more positive learning experience in math and other subjects as well.

Summary

To conclude, the information shared related to my research question on the memorization of math facts comes together to show a variety of big ideas. To begin, it proves just how complicated this topic is and how there are layers of understanding that need to occur. Secondly, it illustrates why math fact automaticity cannot continue to be overlooked in our education system today. It is a disservice to our students and the future of our world. There are several reasons why an emphasis on the retention of math facts has shifted over the past hundred years. Some of these changes were much needed, but replacing it with nothing is not acceptable. Teachers need successful resources and strategies to fix this hole in student's learning.

This chapter went into great detail on a variety of topics related to math fact automaticity. It identified that the system of memorization is complicated and crucial to understand. This allows for more efficient procedures to be utilized that aid the retention process in our minds. It was also discussed how important memorization is in our lives even on a nonacademic level. The timeline of memorization was overviewed as the difference in pedagogies has been seen, especially in recent years. Automaticity is looked down upon in the education setting for various reasons by some. It is also fully supported by others and is a highly debated topic. A variety of successful and unsuccessful math fact learning strategies were detailed. Some of the more successful ones are interleaving, mnemonic devices and regular repetition. Frequent drills and timed tests have been shown to be less successful in the states, as they produce negative feelings towards math. Several studies were reviewed, which studied how math fact retention impacts the overall

understanding of math topics. It was found that these two concepts are related and build upon one another. This brings forth the importance of this topic and how it can truly make a difference in the lives of students. Lastly, different memorization ailments were shared. This has a big impact on the overall ability of students to recall large quantities of numbers. These disabilities and injuries should not be used as an excuse, but should be kept in the mind of the educator to allow for proper modifications and accommodations to be used.

In Chapter Three there will be an explanation of the project I completed related to my research question, *What methods are most effective for teachers to implement with their striving learners to allow them the opportunity to retain their basic math facts?* More specifically, I will be sharing who my intended audience is and where this project took place. I will support my work with the theories and studies I just went into great detail about. For example, research shows an understanding of basic math facts is crucial before memorization can take place. This was the theme of my project and something I often came back to in my work.

CHAPTER THREE

Project Description

Introduction

The purpose of Chapter Three is to give a thorough description of the project I created. My project is based on the findings found in my literature review about math fact understanding and retention. Specifically, the goal of my project was to explore my research question, *What methods are most effective for teachers to implement with their striving learners to allow them the opportunity to retain their basic math facts?* To accomplish this goal I made a website. In this chapter, a thorough description of my website will be done by explaining the project in general, but also an overview of the audience, setting and timeline. I also will discuss why I took the website approach for my project and what research backs up that decision. Lastly, in my conclusion I will summarize the most important parts of this chapter and also introduce the following chapter.

Project Overview

The purpose of my project is to give strategies to teachers, parents and students to assist in the math fact learning process. This learning takes place on a spectrum, beginning with a basic understanding and growing into automaticity. Each phase needs to be understood by all three parties for students to be truly successful. The website I created accomplished this goal by presenting information, games and strategies for all groups to utilize. As an elementary school teacher I have seen the positive and negative effects of fact retention in my classroom. It can be a very empowering subject, or completely deflating. Through grappling with my created project, I hope more students

feel empowerment in their math careers. In the following section I will present the rationale for why there was a need for the project I created.

Rationale

My research question requires layers of information to be understood. The topic of math facts is one that has become overlooked as being surface level material. However, a strong foundation of basic math facts really catapults a pupil further into their math experience. Through the years the use of memorization has varied in school settings. Where education once ran heavily on automaticity, today that is not the case. Teachers are taking on more of a conceptual understanding approach. This is an improvement, however some skills do require basic items to be recalled (Tan, 2014). One such example is in higher thinking math. It becomes difficult for a student to solve a problem finding the area of an irregular shape when the basic math facts become a barrier to computing the correct answer. When teachers go to teach their students basic math facts, they realize there are holes in their curriculum. Teachers use strategies they were taught as children to teach their current students. This often includes timed tests and memorization drills. (Allen, Lyall, 2018) Not only are these activities damaging to student's attitudes and feelings about math, they are not the most effective.

Over time certain strategies and activities have been shown to be successful when it comes to math fact retention. One of the most important concepts for success in completing math facts is a strong number sense. This can be developed through number talks and other mental math activities (Boaler, 2015). When students are able to think flexibly about numbers, they are able to unpack their facts much more efficiently. Another way to set students up for success with their facts is for teachers to use an

interleaving model. This teaching strategy allows for a variety of related topics to be learned, practiced and assessed together. One example would be an exercise where students are utilizing multiplication and division in order to solve different area problems. Research shows that this is much more effective than teaching math facts on their own (McGraw Hill, 2019). One final successful example is using mnemonic devices for certain facts that tend to trip students up in their work. These retention strategies allow students to be more fluent and recall facts more quickly as they solve more difficult math problems. Many of these strategies can help students understand math facts, yet also bring them to automaticity.

Lastly, a wide variety of research and case studies have been conducted on this fascinating topic of math fact retention. Generally speaking, students who know their facts well do better with more advanced topics (Baker & Cuevas, 2018). This automaticity relieves a lot of math fatigue when solving a basic math fact to then figure out the answer to a more complicated problem. An emphasis on math fact understanding and eventually automaticity is so crucial for the development in a child's math career.

Clearly, there is a need for work to be done when it comes to math fact learning in schools. Teachers and parents need to be educated on this topic, so they can better teach their students and children. This includes knowing which strategies are helpful compared to those that do more harm. Also, an understanding of the importance of this topic needs to be fueled in some schools and homes. The website I created is a place where information and resources pertaining to this topic are stored. Not only will the site educate, but it will allow new learning to take place in different capacities. In the next

section I will describe how I accomplished this lofty goal by describing my project in more detail.

Project Description

The project I created combines my own personal experience in education with the research I completed for my literature review. There is a need for direct fact exposure, instruction and practice in school. All of these needs are not taken care of through most math curriculums. The website I made will fill these holes and give the three different audiences the support they need.

There is a plethora of information and resources on my website for people to utilize and explore. To begin, there is information on the importance of understanding and eventually memorizing basic math facts. This includes some statistics from my research to help my users understand the importance of this topic. I wanted all three parties to comprehend the material, so each has their own tab with language and information that is appropriate for them. I believed teachers would benefit from understanding how memorization occurs in our brains and what strategies can be used to improve it. One example of this is interleaving material, instead of teaching it in a block format. When it comes to parents, there is a need for them to understand how math fact knowledge strongly affects their children in later grades and math classes. However, they also must know that understanding is crucial. Requiring their children to participate in drills for long periods of time is not the best solution. This is shown with evidence from different studies over the years. On the tab for students, I want them to see that their ability to recall math facts can be improved upon over time through hard work and

practice. The research correlated to this statement is illustrated with a graphic so students can easily understand.

On my created resource, there are also resources for these various groups of people to use. For teachers it includes successful lesson plans, like the Sieve of Eratosthenes. Not only are there directions listed, but also any materials that are required to teach this lesson and others effectively. There is also a list of strategies such as ideas for number talks, ways to use manipulatives in a meaningful way and how to interleave different subjects. Lastly, there are games that can be implemented either with a whole class, in groups or individually. When it comes to parents, the resource tab looks similar to the teacher's, but activities are ones that can be done at home, which require fewer materials. Some examples are directions for how to make flashcards and other ways to enforce rote counting by various numbers. I also included a tab for students. This includes mainly games that can be played at school or at home. Students are easily engaged in technology, so there are different online games and apps listed. There are also activities they can play with others such as Multiplication War.

My website is a place where learning, support and practice can take place. It houses a plethora of resources to be used by those impacted by math fact fluency. In the next section, I will further propose who my targeted participants are in this project and the setting in which it will take place.

Setting & Participants

As discussed above, my website is aimed towards three different groups of participants. This includes teachers, parents and students. There is a need for all three to understand the complexity of learning math facts in their respective capacity.

When it comes to the setting, I hope to use my website with my fourth grade students for years to come. My team of fellow teachers will hopefully also utilize it with their classes. The resource will also be sent to other teachers in my school in varying grade levels and their students' parents. We often are asked by parents how they can work on math facts at home with their children, and this website will hopefully become a great resource. The suburban school I teach at is very large, with over a thousand students and one hundred staff members. The overall population of our students fall into the upper socio-economic class. Many of our families hire tutors if their children are not understanding content. Our parents are very involved and willing to do almost anything to ensure their child succeeds and is on the right track academically. I believe the avenue of making a website will be really accessible for these parents and they will truly utilize it.

Timeline

In order to complete my website there were a few steps that needed to be taken. To begin I talked with different technology experts about what an appropriate platform would be for me to create my website on. Then I gathered the most important research information for each group of participants. I also ensured the language and information was appropriate for each group. Thirdly, I created a list of the most valuable resources, lessons, strategies and manipulatives for each group when it comes to math fact understanding and automaticity. All the content was then put on the website. After this initial creation of my project, I tested the website out with my class to see if there were any issues or kinks that needed to be worked out. Once the modifications that were

needed were completed, I sent the website to parents and other staff members to utilize with their children and students.

Framework & Methodology

Since I am reaching such a wide variety of people when it comes to math fact understanding, I decided to make a website. It will allow all parties to benefit in their appropriate capacities no matter their role in this topic. By reaching such a variety of participants, different frameworks have been considered to make my project successful. I will discuss my findings in the following paragraphs.

When it comes to adult learners who will be accessing this website, there are a few items to keep in mind. The first is that adults thrive when appropriate technology is utilized and it is up to date. Not only does this keep them engaged, but it also gives ideas for what they themselves could utilize in the future (Knowles, 1980). This is something I kept in mind as I included different activities and presented my research. Knowles goes on to say how adult learners also need room to be creative and interpret the information in their own way. In order to accomplish this goal I worked on being specific, but also suggested activities that can be made their own.

Children from various grade levels will also be a large portion of the audience utilizing my project. Backwards Design is a unit creation strategy that has shown much success with students. Backwards Design focuses on the end result first and then plugs in lessons and activities to meet that goal (Gonzalez, 2020). Keeping this in mind, I kept my final goal of math fact fluency as the forefront of my work. I then pulled strategies to guide students to this goal. It started out with more basic understanding ideas and grew into the emphasis of faster recall.

When it came to making a website there were many things to keep in mind in order to make it useful and an enjoyable experience for all participants. One suggestion from the Research-Based Web Design and Usability Guidelines is to plan backwards, similar to Backwards Design described in the previous paragraph. Secondly, as the website designer I should focus on the content before working on colors, fonts and pictures. This resource also encourages using parallel design. This concept includes looking at various sites with similar content and creating a blend of styles and designs to be successful (Department of Health and Human Services, n.d.).

When I created my project, considering adult and student learning needs was crucial. Additionally, understanding how to present the content appropriately went a long way in reaching my goal. These frameworks kept me focused and prevented potential hurdles for my audience.

Summary

In this chapter it was discussed why there was a need for a website to be created centered upon math fact acquisition. Not only are there holes in math curriculums on this topic, but teachers and parents do not understand the best approaches to teach. This project will benefit teachers in the classroom, parents at home and students in and out of school. Through the creation of it, hopefully children will better understand and become more fluent in their math fact skills. This will occur as they and those who teach them grapple with the various strategies and research platforms presented on the site. The next chapter will serve as a conclusion to my research, project and rationale for my research question.

CHAPTER FOUR

Conclusion

Introduction

Throughout my teaching career, I have had hundreds of students in my classroom for math instruction. I have taught extremely gifted students and students who were striving to meet grade level standards. No matter the level of math at which they performed, there was always a common denominator: Students who were able to recall their math facts efficiently and correctly soared greatly when it came to their math journey. Unfortunately, the opposite was found with students who were unable to automatically compute their basic facts.

As a teacher, this was challenging to witness year after year. I noticed holes in the curriculum I taught. Multiplication was taught in two separate units throughout the year. There was little done with moving basic facts from an understanding to memory. This caused roadblocks with future math topics and was frustrating for everyone. These observations are what fueled my passion for my Capstone Project on the automaticity of math facts. My research question is: *What methods are most effective for teachers to implement with their striving learners to allow them the opportunity to retain their basic math facts?*

In this final chapter I will reflect upon my project as a whole. I will discuss how I created my website with the goal of assisting students, teachers and parents with math fact automaticity. This will include some of the challenges I came across and how I was able to implement my created resource with my current fourth grade students. Then I will describe how my Literature Review in Chapter Two assisted me in the making of my

website. Several resources were specifically helpful, so I will highlight them and the information I used in my project. Next, I will share the implications and limitations of my designed site. Lastly, I will share next steps for myself and other researchers as related to math fact automaticity. In this next section I will explain how I created and implemented my website.

Creation & Implementation

Throughout this capstone process, I have become a stronger researcher, writer and learner. It has been a very valuable experience as an educator. I became a student; my role was reversed as I immersed myself in information and made sense of it. Specifically, I quickly learned what sources were helpful and which to avoid. I also became fluent in quickly summarizing studies to assist myself in trying to answer my research question. I was then able to take my gained knowledge and turn it into words that students, teachers and parents would be able to understand. Lastly, I personally learned so much about math fact automaticity and how to better instill this knowledge into my students.

One challenge I quickly came across on this journey was how to actually create a meaningful website. It sounded so easy at first, but it took a lot of planning. I had the extra challenge of presenting information to three separate audiences. Obviously, students needed information presented in friendly terms, compared to a teacher who has more background knowledge. I also wanted to be intentional about the information I shared with each group. Big studies centered upon math fact retention predicting future math success would not be appropriate for students to know. However, it may be helpful to a parent and/or teacher to understand.

One way I was able to combat this roadblock was to sift through my Literature Review. I copied big takeaways and then pasted them into a separate document. I had a category for students, teachers and parents. Then when I went to actually create my website, I had some solid ideas to propel me forward. It kept me focused and steered me away from becoming overwhelmed with all the information.

Another issue I came across was navigating the technology. I had never made a website before, so it was very tedious and frustrating at first. However, after some trial and error and reaching out to colleagues more fluent in the website creation world, I made a lot of progress. Near the end of my project I was much more efficient and confident in my ability to create a site!

When it comes to the implementation of my project, this was my favorite part of the process! I began by sending my website to my immediate family. I had them do a quick spot check to ensure all the links were working and that the site had no visual issues. I then sent it to my professor, content reviewer and fellow fourth grade teachers. I wanted them to critique it more as a potential user. Lastly, I gave it to my students and their parents for the final test.

I received a lot of positive feedback! The comments from my student's parents meant the most to me. Many of them shared how they did not know how to help their child with basic facts besides drilling them over and over. One parent even shared how she now understood the importance of understanding before memorizing. In the month since I have shared it with my main audience, I have been pleased with its ability to reach so many people and be helpful in different capacities. In this next section, I will go over

the most critical resources in designing my website, which I discussed earlier in my Literature Review.

Literature Review

As I mentioned above, I went through my Literature Review right at the beginning of my website creation process. When I did this, there were four main resources that made an appearance several times. They were extremely helpful in the creation of my website as I presented research, tips and resources to students, teachers and parents.

When it comes to the information on memorization, The Derek Bok Center for Teaching and Learning was really helpful. This resource broke down how our brains memorize information. I found it critical as a foundation for my project to understand how memories form and can be recalled. It even went into the difference between knowing basic facts and being able to use those basic facts to solve a more complicated problem (The Derek Bok Center for Teaching and Learning, n.d.).

The bulk of my project was centered upon the retention of math facts. This included a variety of subtopics. For a better understanding of how to best teach math facts, a website done by McGraw Hill had a lot of helpful information. For example, they listed the three stages of fact automaticity: counting, strategies and mastery. They also emphasized how going through each of these stages is critical (McGraw Hill, 2019).

Another subtopic of fact automaticity was the link between fact knowledge and future math success. To better understand this concept, I relied mainly on the research done by two different groups. Brewer and Cuevas shared a study, which showed that fact automaticity does impact future math thinking. They accredited this to the mental load

being less when approaching problems. Students who know their facts well can get started instantly on a problem, instead of spending a lot of time trying to determine the fact itself (Baker & Cuevas, 2018). Secondly, Brewer and his research group found that fact retention in fourth and fifth graders greatly determined future math success. They did not find these same results for third grade students, which is interesting (Brewer et al., 2017). These two studies really fueled the "why" behind my project. It became clear that becoming automatic in basic facts is important for all learners to one day achieve. Next I will go over the implications and limitations of my created website.

Implications & Limitations

My hope is that the website I created is helpful for students, teachers and parents. More specifically, I want it to fuel the success of students for years to come in math. When it comes to students I hope they feel inspired and motivated to not only understand their multiplication facts, but also move them into memory. The games I listed are engaging and fun, so it becomes less of a chore. For teachers, my desire is that they have resources to access and the proper knowledge to teach and reinforce math facts in their classroom. This includes several lesson ideas, which are best practice. Plus, they reinforce an understanding of multiplication facts. Lastly, for parents I hope their toolbox is filled with ideas on how to correctly teach math facts and what to avoid, as all strategies are not the most effective. Math has the potential to be exciting and empowering. In order for this to happen, students need to have a solid foundation and understanding of their facts. However, the step of automaticity needs to occur also in order for true success to take place.

The biggest limitation of my project is that its success relies on the action and receivement of the user. In a sense, I no longer have control over what happens with my website. I am able to implement it with my students in my classroom. However, I am not able to enforce its use across the grade, school and even at home. If parents never open the website, they will be missing out on the resources and information I have provided them. Another limitation is that parents may access my website and either begin or continue to use fact retention strategies that are not effective. For example, parents may open their research tab, become overwhelmed with the task ahead and close out of the website. They may have their child drill facts over and over, instead of making it more engaging with a game. They may also emphasize memorization before a solid understanding has taken place.

I believe the implications of my website overpower the limitations. If it even helps one student, teacher and parent it has been successful! In the next section of my paper, I will go over some next steps when it comes to my topic of math fact automaticity.

Next Steps

I believe the area of fact automaticity has the potential to be studied in a variety of different capacities. My research and website were concentrated on multiplication facts. However, it would be interesting to look into addition, subtraction and division basic facts in varying grade levels. I would presume that having a solid understanding before memorizing will be consistent across all kinds of facts. However, the question becomes what strategies are the best for learning these operations?

In the future, I think it would be interesting for myself or others to create a curriculum that emphasizes the understanding and eventually memorization of basic math facts. There are a lot of great resources out there that would serve as a solid foundation to this work. As an educator, it can be overwhelming to have so much information. Having everything in one place is helpful in ensuring the content is taught properly.

For myself personally, this journey on math fact automaticity is just the beginning. I will use my website with my students for years to come, as long as it continues to be helpful to the targeted audiences. I can see myself adding to it over the years as I continue to immerse myself in this topic. Eventually, I hope it can become a district level resource that students, teachers and parents can use from year to year. Specifically, when it comes to sharing my results I will first share it with my principal and then other staff at my building. At one point, my principal mentioned having me give some Professional Development related to fact automaticity. This would be a great time for me to highlight my created website. In the future, I will continue to emphasize this topic with my students, teachers and colleagues. My website serves as a great foundational resource to propel this work.

My created website is a benefit to the teaching profession because it emphasizes how to build fact fluency, yet also shows why this topic is important. It targets the three audiences that have an influence on when and how this learning takes place. I believe it has the power to help a large variety of people! In this last section of my capstone, I will summarize my key takeaways from this fourth chapter.

Summary

Like I have stated several times in this paper, math has the ability to be empowering and exciting. A big piece to achieving this goal is having concrete strategies to efficiently solve multiplication facts. Without this understanding and recall, math becomes frustrating and unapproachable. My passion for this topic fueled my capstone project. Through this process my dedication has become even greater as I have researched and become so invested in the world of fact automaticity. In this chapter I reviewed how I created my project and then implemented it with my target audiences. I shared the success I had with my students and their parents as they grappled with my resource for the first time. Then I went over the key sources I used in the creation of my website, which stemmed from my Literature Review. This included a few case studies and other general research related to memorization and fact automaticity. Next, I discussed the implications and limitations of my project. This included how I hope my project is used in the future, but also ways that I am limited with my end result. Lastly, I shared the next steps to be taken by myself and other professionals who are interested in studying fact automaticity.

At the beginning of this chapter, I stated how in my experience students excel or struggle based on their ability to solve multiplication facts. After immersing myself in research and also creating a project, my ability to teach students, teachers and parents about this topic has increased exponentially. I now have the research to back up what I have seen in my own students. I also have the tools to overcome negative feelings about math that stem from fact knowledge. I want to foster empowered students who can solve

any math problem, both in school and real life. My capstone process has helped me to achieve this goal.

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