MATH FLUENCY GAMING AND ITS IMPACT ON STUDENT ACHIEVEMENT

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CERTIFICATION OF APPROVAL

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DEDICATION

For Juan, Johnny, Noah, and Emmy.

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ABSTRACT

This thesis examined the impact of the amount of fluency gaming on student achievement in mathematics. Three second grade classrooms and three third grade classrooms were included in the sample. The second grade classrooms used a variety of math fluency gaming practice programs, while third grade students mainly participated in FASTT Math. The amount of fluency gaming time varied in each classroom. There was no significant difference in math achievement scores second grade students received on their unit tests based on amount of fluency gaming use. In third graders, there was a significant difference found in the scores. Students who participated in high amounts of fluency gaming had a higher cumulative achievement score than medium and low fluency gaming users. It was also hypothesized that students who participated in fluency gaming would score higher in the first unit of the next grade level; however, there was no significant difference found. Results are discussed.

CHAPTER I

INTRODUCTION

Basic arithmetic skills are used by people every single day. Proficiency with arithmetic skills is the ability to use addition, subtraction, multiplication, and division in a quick and accurate manner. When these four operations can be used in an effortless way, students have achieved mastery. If they have achieved mastery, students have therefore achieved automaticity which allows students to solve problems and learn new concepts easily because they have freed up their working memory (Geary, 1994). Solving problems using basic arithmetic is necessary when purchasing goods, finding the better deal, or doubling a recipe for unexpected dinner guests. Dozens of occupations use numbers to communicate outcomes and demonstrate measurements. Businesses use numbers daily to figure out profits and losses, while accountants use them to keep track of spending and gains. Numbers can be seen everywhere from movie theatres, to billboards, and monitoring patients in a hospital. All types of individuals need numbers and basic computation skills to do their job. In the school setting, elementary teachers teach basic arithmetic skills in order for students to progress to higher level math skills in courses such as algebra, geometry, and calculus.

Since mathematics is incredibly important in all aspects of life, there are international studies on mathematics. One such measure is the Trends in International Mathematics and Science Study also known as TIMSS. This study is conducted every

4 years to measure achievement in advanced math and science. The data are collected from fourth and eighth graders at the end of the year. There are 49 International Association for the Evaluation of Educational Achievement or IEA countries that participate in the fourth grade assessment, and 38 countries in the eighth grade assessment. The results range in scores from 1-1,000, with the U.S. having an average of 539 on the math assessment in 2015 which was higher than 34 of the participating education systems.

When looking at TIMMS scores in the most recent assessment there were 21 districts in the United States that participated. The proficiency range for the 21 districts ranged from only 5-51%. Most districts fell in the No Change or Score Decrease category from the previous assessments. Similarly, in 2010, the United States Secretary of Education Arne Duncan released a statement that mentioned overall mathematics scores on the National Assessment of Educational Progress had only slightly risen but were nowhere near scores students have had in the past. This shows that although U.S. schools are making steady changes in the mathematics curriculum, the country has still not seen growth among students (Provasnik, Malley, Stephens, Landers, Perkins & Tang, 2016).

Statement of the Problem

In a third grade classroom, much of the first two quarters entails learning multiplication and division facts with automaticity. When students have developed automaticity, they are able to recall the facts quickly and correctly. A component of math instruction in a third grade classroom involves fluency gaming. Fluency gaming can best be described as a computer driven game where students are presented with basic math facts and must respond quickly to progress through various levels. A common complaint among fourth grade teachers is how much the students have forgotten math facts over the summer and having to reteach multiplication. This can make some third grade teachers feel as though they are failing since students work so hard during the school year to learn and memorize those basic facts. If students have developed fluency with basic arithmetic facts in the previous grade level, it frees up the teacher to continue with more difficult math, for example, long division and multiplying two and three-digit numbers. Fluent students are able to multiply, divide, add and subtract fluidly and with little effort. However, for many students, fluency is not achieved during third grade.

Although there are many studies on different types of strategies for achieving fluency, there has not been a study done on the effectiveness of fluency gaming on math achievement scores. These achievement scores, also known as benchmark scores, can be commonly explained as a summative assessment that students complete at the end of the unit. For example, in third grade, the first two quarters in mathematics focus on multiplication and division. The first unit focuses on multiplying by 5s, 2s, 9s, and 10s. The opposite operation, division, is learned alongside multiplication. In one urban school district in California the curriculum being used is Math Expressions by Houghton Mifflin which does not contain a fluency gaming component. The district has purchased several fluency options for the school including Big Brainz, and FASTT Math which is a Scholastic program. The use of fluency gaming is not required nor has a set required time been designated for its use in the classroom.

Many teachers want to use technology but have a variety of reasons why it is not used. One reason teachers may not be using technology in the classroom is that they simply do not know how to fit a consistent practice of fluency into the already overloaded curriculum. Although pacing guides are available to teachers, there are still some parts of the curriculum, like Unit 5 which is a unit with two step word problems, that get left out each year because of time restrictions. Teachers who do not feel comfortable using technology or feel that it is too difficult to implement may choose to stick with more traditional curriculum. In many districts, there is little funding allocated towards professional development, training that might help teachers feel more comfortable integrating technology.

Some districts have not quite transitioned to become 1:1 schools, which means that there are not enough devices for students to use on a daily basis. There are hundreds of math apps and software programs that various schools have implemented. However, when schools do not have enough technology, teachers are able to use fluency gaming and other instructional resources in only a limited capacity. These students are not able to practice their math facts using technology because it simply is not available. The purpose of this study was to examine how using fluency gaming in the classroom affected performance.

Significance of the Study

In the classroom, educators possess a variety of techniques and strategies for teaching multiplication and division. The curriculum suggests many ways as well, for example skip counting or using fingers for multiplying by 9s. There is little research on the strategies that are most effective in helping students learn the information. Although there are many strategies out there, each student is different and learns at a different pace. If districts are spending money on programs and software, then it would be beneficial to examine whether what is being used really is effective. It would also benefit school districts to see how much math achievement can be impacted by amount of time allocated for students to practice math facts using fluency gaming software. If math achievement in the primary grades can really be supported by using consistent fluency gaming, districts might invest more time in professional development for the programs already in place.

Research Question

How does using fluency gaming in math affect performance?

Hypotheses

H-1.1 Students who participate in regular fluency gaming will have a significantly higher performance score on the unit exams than students who do not regularly use fluency gaming.

H-1.2 Students in the second grade who regularly participated in fluency gaming will have a significantly higher performance score for the first unit in third grade than students who did not regularly use fluency gaming.

H- 1.3 Students in the third grade who regularly participated in fluency gaming will have a significantly higher performance score for the first unit in fourth grade than students who did not use regularly use fluency gaming.

H- 1.4 Students in the third grade who regularly participated in fluency gaming will have a significantly higher performance score for the first unit in fourth grade than students who did not use regularly use fluency gaming, after controlling for third grade mathematics achievement on the SBAC.

Theory

The theory of cognitive development explains how a child develops a mental model of the world around them (Piaget, 1936). Piaget disagreed with the idea that intelligence was an inherent trait. He believed that cognitive development was a process that occurred due to maturation biologically and interaction with the environment. Piaget described three basic components to the theory of cognitive development: schemas, adaptation, and stages of development. A schema is essentially a building block and a way of organizing information. Piaget was an evolutionary biologist who believed that all organisms had to adapt to survive. He believed that intelligence happens in biological organisms and therefore organisms are able to adapt. The stages of development relate to different periods in a child’s life where certain cognitive processes are developed (Piaget, 1952). Since this is so, students are ever changing and continue to develop throughout the lifespan. Even though Piaget did not exactly relate his theory of cognitive development to education, many of the ideas apply. Piaget discussed maturation and the idea of being ready for certain concepts. In this study, participants were between the ages of 7-9 when they are beginning to develop logical thought. This stage is a time when students are ready to learn basic mathematics facts.

Children learn best when they are active learners rather than passive. In the concrete operational stage children are beginning logical or operational thought which is why at this stage, ages 7-11, children are able to work things out mentally (Piaget, 1952). During this stage, children can conserve numbers, weight, and mass. Since children develop certain concepts around particular stages, it would be advantageous for educators to take into account the developmental readiness of students for basic arithmetic. In the primary grades, the main focus in mathematics is to develop fluency so students are able to easily solve higher level thinking problems once they are cognitively ready to do so. Fluency is the ability to respond in a quick and accurate manner (Parkhurst, Skinner, Yaw, Poncy, Adock, & Luna, 2010). When someone is a fluent speaker, he or she is able to hold conversations with appropriate speed and accuracy. In mathematics, teachers often discuss students learning basic math facts like addition, subtraction, multiplication, and division with automaticity. Automaticity is the ability of a student to answer a specific fact with ease, accuracy, and speed (Parkhurst et al., 2010). As Parkhurst et al. (2010) discussed, basic academic skills are often needed to learn and master more advanced skills (p. 118). A primary classroom places great importance on learning basic math facts fluently and automatically. It is essential for students to develop fluency in mathematics in order to master more complex concepts in the future.

Cognitive load theory is a theory that was developed during the 1980s and has continued to develop due to continued research worldwide. It is a theory that brings together the structure of information and cognitive architecture which helps learners process information (Paas, Renkl, & Sweller, 2003). Cognitive load theory contains three categories, the first of which is intrinsic cognitive load. The main element of intrinsic cognitive load is element interactivity. It is called intrinsic load because the demands on working memory capacity are the core of the material that is being learned. Working memory is the system in which all conscious cognitive processes occur (Paas, Renkl, & Sweller, 2003). Individuals can only handle a small amount of new information at a time, specifically two or three elements, until it has been stored in long-term memory. This helps to explain why developers of FASTT Math present 2-3 focus facts at a time. Limiting the amount of new material presented reduces strain on working memory. This theory also deals with the interaction between the structure of information and cognitive architecture. If a learner is given information that obstructs the achievement of building schema and automation it is known as an extraneous or ineffective cognitive load (Paas et al., 2003). It is incredibly important to structure instruction so that schemas may be built upon. The last component of the cognitive load theory is the germane or effective cognitive load. Extraneous cognitive load hinders learning, while germane cognitive load enriches learning. Germane cognitive load is guided by the instructional designer (Paas et al., 2003). A build up of effort or motivation can increase cognitive resources as a student performs a task. If the information is pertinent to acquiring and developing schema and automation, there will be an increase in the germane cognitive load (Paas et al., 2003). When students are developing automaticity and fluency through online gaming, the cognitive load is manageable because students give effort and are motivated by the task.

When students practice basic arithmetic through fluency gaming, they are participating in individualized animated practice. In the fluency program Big Brainz, students become an avatar in the game and must move through the various levels, and because of this animation and repetitive presentation of facts, students gradually achieve automaticity. Big Brainz also presents learners with 2-3 focus facts that are presented during a session. Learning and practicing basic math facts becomes a game rather than rote memorization and recitation. In the gaming environment students understand which facts they are studying and which ones have already been mastered. Students are excited to see the progress made throughout the school year but also excited to move through visually stimulating worlds of math facts.

Definitions

Automaticity- the ability of a student to answer a specific fact with ease, accuracy, and speed (Parkhurst et al., 2010).

Big Brainz- a software program geared towards primary students. The software program allows students to choose an avatar and explore various worlds while solving basic arithmetic problems.

FASTT Math Next Generation- Scholastic fluency gaming program that chooses 2-3 fast facts for students to focus on. Facts are presented rapidly to students in groups of 60 problems.

Fluency- the ability to respond in a quick and accurate manner (Parkhurst, Skinner, Yaw, Poncy, Adock, & Luna, 2010).

Fluency gaming- online technology program that presents basic arithmetic facts as practice for students.

Summary

Basic arithmetic skills are an important foundational tool that is taught in the primary grades. The ability to add, subtract, multiply, and divide are needed to develop higher mathematical reasoning. A way teachers can help students to develop fluency and automaticity with basic math skills is to use fluency gaming. The literature review section in the next chapter focuses on practicing basic math fact fluency using online gaming, and various studies on a wide range of computer based fluency gaming programs and how they helped at risk students. The chapter will also summarize studies examining motivation and engagement during computer gaming to help students practice facts as well as how and why teachers are integrating technology into the classroom.

CHAPTER II

LITERATURE REVIEW

The focus of this literature review is on basic math fact fluency and computer based interventions. In reviewing the literature two main themes arose which were understanding fluency and basic math facts, and computer based fluency gaming. A review of the literature on fact fluency in mathematics emphasized three key ideas. First, a great portion of the research in math fluency focuses on struggling and at-risk students. Next, research on computer based learning is examined. Finally, research on technology integration in the classroom is presented.

Fluency in Mathematics

One area of importance regarding math fact fluency is the way in which students memorize basic combinations. According to Baroody, Bajwa, and Eiland (2009), there are three phases in which children remember the basic combinations of addition/subtraction, and multiplication/division. In the first phase, they essentially employ counting strategies by using objects or verbal counting to figure out the answer. In the second phase, they tap into reasoning strategies by using facts that are already learned. The third phase, mastery, is when students begin producing answers from memory. People learn in all different types of ways and respond to various strategies. Technology can support a vast number of individuals by presenting topics in unique ways. Jackson, Gaudet, McDaniel, and Brammer (2009) discussed how technology can be incredibly effective with software that gives students immediate feedback. Programs that focus on students' ability to recall basic math facts provide immediate feedback as well as a strategy to solve the problem the next time. Oftentimes, software programs are very visually stimulating for the learner, which can be a benefit for students who need to visually process information. Students may also appreciate the background music and enhanced learning in this manner**.**

Since cognitive abilities play a role in math fluency it is important to understand the relationship between the two. Ramos-Christian, Schlesser, and Varn (2008) investigated the relationship between math fluency and cognitive ability. The study was conducted with 38 first and second grade students. Researchers hypothesized that students at the concrete operational stage would differ significantly on math fluency from those students who were in the preoperational stage of development. According to Piaget, students enter the concrete operational stage somewhere between the ages of 7-11. Researchers also hypothesized that concrete operational students would differ significantly from the preoperational students on the speed of completing basic arithmetic calculations. The study involved 22 females and 17 male students. The independent variable was cognitive developmental level and the dependent variables were fluency, percentage correct, as well as the number of basic arithmetic problems attempted. To assess fluency, researchers used the Woodcock Johnson Tests of Achievement, 3rd Edition (WJ-III). This fluency subtest asked the student to complete as many single digit addition, subtraction, and multiplication problems as rapidly as possible in a 3 minute time span. The task determined accuracy, speed, and fluency using the total number of correct verses incorrect responses. Speed was determined by how many total questions were answered. Fluency was then determined by joining the accuracy and speed result. The study found that concrete operation children and preoperational children differed significantly on math fact fluency. An analysis of variance conducted on the math fluency subtests of the WJ-III scores showed a significant main effect for cognitive development level, $F(1,28) = 12.82$, $p < .05$. The study showed that concrete operational children had greater math fluency than preoperational children. Consequently, since cognitive ability has so much to do with the ability to develop math fluency it is important to understand that some students in first or second grade are simply not cognitively ready to retain basic facts and may need more time to learn them than students in the subsequent grades.

In a study conducted by Carr, Taasoobshirazi, Stroud, and Royer (2011), 178 second graders participated in a randomly assigned experiment in which they were assigned to 1 of 4 groups. The first treatment was a computer program that helps to increase fluency in addition and subtraction. The second treatment was a program designed to develop cognitive strategy use for addition and subtraction. The third treatment was a combination of cognitive and fluency strategies, while the fourth was a control group. The intervention groups participated for a total of 20 weeks with each group receiving two 30 minute sessions per week. During analysis, researchers found that students in the combined fluency and cognitive strategy condition did significantly improve their mathematics achievement when compared to the control group, $F(15, 456) = = .520$, $p < .05$. Gender was also examined and it was found that boys advanced from the intervention while girls did not.

Another area of literature concerning fact fluency tackles the topic of interventions for students who are developing math fact fluency with automaticity. In one case study by Smith, Marchand-Martella, and Martella (2011), a first-grade student was identified as being at risk for math failure. The participant in the study, John, was identified for being at risk because he was a student who was diagnosed with Attention Deficit Hyperactivity Disorder. He fell under the category of Developmental Delay with social and adaptive deficits. A program called Rocket Math was implemented for six months. Rocket Math is an intervention program, where initial fluency was determined using pre-and post-test worksheets. The worksheets presented contained basic math facts that progressed in difficulty. Each new sheet contained two new facts. Rocket Math involved precision teaching that helped increase fluency and accuracy by using methods like skip counting. The data that were collected from John were mainly one-minute fluency checks that recorded his average errors and average problems correct. Results showed that this type of intervention program was effective when combined with the current curriculum because John increased his number correct from 10 to 21 on the post test.

In another intervention discussed by Poncy, Skinner and Axtell (2010), DPR or detect, practice, and repair is a multicomponent intervention that is used to enhance basic math facts which students have not yet mastered. DPR first begins with a fluency assessment that is administered to a group or class. Next, the participants must be reassessed to find the incorrect facts. After the problem facts have been detected, the CCC procedure is used. The CCC, or cover, copy, and compare, is the practice part of the DPR when procedures are completed by the student to practice those facts. It is said that all three of the steps in combination allow the student to actively respond to and detect problem facts that can help lead to fluency. The participants in this study included seven, 8-10-year-old students in the third grade. Initial data were collected using experimenter constructed worksheets that increased in difficulty. Researchers divided 36 multiplication facts into three problem sets that included 12 problems on each new worksheet. This assessment was given at the beginning of each math period before implementing the detect, practice, and repair model. In the last phase of DPR, or repair, students had to complete as many problems as they could in one minute. Assessment was based on digits correct per minute (DCM). The results of this intervention showed that there was an upward trend for two out of three data sets that were collected. The mean fluency performance increased by 8 DCM on the second day of treatment. All seven students increased their DCM between 5.1 and 18.9. This research provided strong evidence that DPR procedures were able to increase fluency which showed a 63% rise in DCM score over the two-week period. After students worked on the 1 minute speed drill, fluency was self-graphed. The drill included basic multiplication equations in no particular order. Facts that were answered incorrectly were covered and then completed again. Results showed that this type of self-monitoring was an efficient method to help students increase fluency (Poncy et al., 2010). There continues to be questions about the learning rates of DPR and how they compare to rates achieved via other interventions.

Computer Based Fluency Gaming

An area of literature concerning computer based intervention examined iPad technology. A particular study done by Zhang, Trussell, Benjamin, and Asam (2015) found that the use of math apps can be an effective support for students who are struggling as well as students with a disability. The apps included were Splash Math, Motion Math Zoom, and Long Multiplication. This study took place over a one-month period at a public elementary school in a fourth grade classroom in a city in southwestern United States. Participants included seven girls and 11 boys; 17 of the students were Hispanic and one was African American. Within this group, four students were identified as students with special needs, and six of the students were identified as being at risk and receiving additional services. During the math apps intervention time period, students participated in 80-90-minute sessions over the course of one month, each session using a different math app. The students used the apps in four different sessions. Each session used a different math app for the 80-90 minute time frame was divided up into segments for each of the math apps. Only one app was used in each session. The first 5-10 minute segment were spent with teachers teaching the students how to use the app. They were then asked to solve a problem set on Splash Math that included 24 questions in a time span of 40 minutes. The students were told that they needed to pass at least 20 of the 24 questions before they could move onto the next set of problems. In the next segment of the session, they would then receive instruction on how the app was used participate in playing the app. In the second session used Motion Math Zoom for roughly 30 minutes. In the third session, the Splash Math decimals section was used. In the fourth session, students used Long Multiplication for a 60-minute time period. There were three paper and pencil assessments given to the students to measure learning from each of the apps. Teachers were able to track progress using the apps and help students with the pace of future instruction. A *t*-test was run to determine if there was an overall difference in the performances of students. The *t*-test indicated significant improvement from the pre-test to the post-test of Assessment 1 ($t(16) = 3.872$, $p < .01$). The mean score went up from $M = 10.7$ ($SD = 4.58$) to $M = 12.5$ ($SD = 4.30$). Results indicated that those who participated in the intervention over the course of one month had significantly larger gains than those who did not (Zhang et al., p. 187). Researchers suggested that if the amount of practice were increased, the intervention could be more effective because the skill is repeatedly practiced. If students are able to practice with these fluency games in the classroom, they could develop fact fluency throughout the year and not just for the unit being studied. Fluency skills could be emphasized during all parts of the year as spiral review when using fluency math games.

In a comparison study (Nelson, Burns, Kanive, & Ysseldyke, 2013) found that students in a math fact rehearsal intervention group had higher retention rates for fluency than those participating in a mnemonic strategy approach. This study included 90 third and fourth grade students from two different suburban schools in Minnesota. Students chosen were those who fell below the 25th percentile on the district standardized tests. The software program used for the math fact rehearsal group was Math Facts in a Flash by Renaissance Learning (2003), while the second group used a mnemonic intervention called Times Tables the Fun Way, that used rhymes, words, stories to help remember difficult facts. Mnemonic intervention is a type of intervention that helps students trigger difficult facts by using rhyming sentences and stories. The dependent variables assessed in this study were retention and application measures. Retention was measured by using 20 single-digit multiplication problems in 3 minutes. Students' posttest scores were compared with pretest scores from the beginning of the study. The outcome was achieved by dividing the total number of digits correct per minute by 3. Application of learned facts contained 18-word problems that involved digit groups of the facts recently learned. Most students needed roughly 25 minutes to complete this assessment. Students were split into three groups, the Computer-Delivered practice intervention, the Mnemonic Strategy, and the Control group. Each group contained 15 students for a total of 45 in the Digits 6-7 group and the same number of students in the Digits 8 to 9 sub-groups as well for a total of 90 students.

The researchers (Nelson et al., 2013) found that during the posttest, the students who were assigned to the computer based intervention group had the highest mean in digits correct per minute score ($M = 7.10$, $SD = 4.21$), closely followed by the mnemonic strategy group ($M = 6.51$, $SD = 4.12$), and the control group ($M = 5.13$, $SD = 2.51$). There was a significant main effect of group assignment on the digits correct per minute when controlling for the pretest retention score, F (2, 81) = 3.26, p

= .04. Even though both groups showed higher digits correct per minute than the control group, only the computer based intervention group (MFF) showed a significantly larger score than the control group (p = .04, d = .27). None of the other group comparisons were statistically significant. In regards to fact fluency, students in the computer based rehearsal group showed higher fluency scores than students in the mnemonic strategies group and control group. This study helps to display the benefit of computer based math fact rehearsal practice and how it can help struggling students.

Technology Integration

There are several areas of research discussing the integration of technology in the classroom for the purpose of fact fluency. Research has highlighted the various perceptions of teachers in regards to technology. In addition, the impact of technology on student motivation is examined.

One area of integrating technology into the classroom to develop math fluency is teachers' perception about using technology for learning. As Ertmer, Ottenbreigt-Leftwich, Sadik, Sendurur & Sendurur (2012) found, the beliefs and attitudes of teachers were the biggest determinant of the success of the student. Ertmer et al.'s study was a multiple case-study design in which the purpose was to look at the similarities and differences between pedagogical beliefs and technology practices of 12 classroom teachers. These teachers ranged from grades K-12. The participants were selected based on purposeful sampling; some teachers were award winners and others had been recognized by the International Society for Technology in Education

(ISTE). There were seven females and five males with experience ranging from 2-31 years. Eleven of the participants were core-area teachers and one was a computer teacher for his high school. In one survey teachers were asked to rate on a scale from 1-5 on the extent to which barriers impacted their students' use of technology. Teachers reported that they did experience external barriers but they found ways to solve and break through the barriers within their own classrooms. Some barriers that teachers discussed were money, technology access, time, knowledge and skills of students. However, the barriers that impacted them most were external barriers like support, state standards, money, access, time, and assessments. Although technology may be widely available, use still depends on the individual classroom teacher. According to Ertmer et al. (2012), "teachers were able to enact technology integration practices that closely aligned with their beliefs" (p. 432). Essentially if teachers believed that technology was best used for collaboration, teachers described projects where their students used technology to collaborate. Internal factors regarding technology like passion, problem solving, and support from administration also were factors for the integration of technology (Ertmer et al., 2012).

Over 50% of teachers in one study agreed that technology increases student engagement (Carver, 2016). In this study, 68 graduate level students were surveyed in an online course. The participants of the study were asked four open ended survey questions. The questions asked about barriers faced in implementing technology into the classroom, benefits of integrating technology, factors that impacted frequency of use, and the factors that impact purposeful use. The survey was anonymous; 74% of participants taught reading or language arts and almost two-thirds taught STEM classes. Of the participants 41% taught in grades K-2, and 33% taught at the intermediate elementary and middle school levels. The survey revealed that 89% said they used a digital projector at least weekly, while only 56% reported that they used an interactive whiteboard. Forty-eight percent of the respondents said that they used an iPad digital camera at least once a month. Of the participants surveyed, 59% of the teachers said that technology increases student engagement. This study shows more and more teachers are using technology to help engage students. When teachers can engage students, they can help them learn. If students can be engaged in a fluency program then they may further their understanding of core concepts in math.

As Zhang et al. (2015) found, students were engaged when they were working on an app. The ability to hold a device in their hands and complete math problems with visuals allows students to be motivated and excited about learning and demonstrating knowledge. Often apps are very colorful and stimulating in their design. In a study done by O'Malley et al. (2013) to investigate the effects of basic math skills using an iPad for fluency in the special education setting, teachers perceived iPads as having "a positive impact on engagement and interest" (p. 2). Students were delighted with the chance to use an iPad since it gave them a chance to interact with technology. According to Delen and Balut (2011), when students use computers, it can help sustain visual attention because many times the programs are asking users to self-monitor. For many of these fluency apps and software programs, students must navigate through obstacles while keeping track of a few focus facts that are presented during the lesson.

Summary

A major theme that arose in reading about students' developing fluency was cognitive ability. If students are not cognitively ready to receive instruction, they are less likely to learn their basic facts fluently. Students in the concrete operational stage are more likely to develop fluency and accuracy of basic math facts rather than students who have not yet reached concrete operational stage of development. A theme in previous studies with struggling students was using computer technology to practice facts can be beneficial for at risk students or students with low achievement. Students receiving computer based intervention, whether it was on the iPad or another device, seem to do well when learning facts using math rehearsal. In regards to technology integration in the classroom, educators found that devices could create engagement and motivation but could sometimes be hindered by the teacher's lack of experience or lack of devices.

CHAPTER III

METHODOLOGY

An elementary school's second and third grade students were analyzed for the amount of fluency gaming provided by the teacher and achievement scores for each unit of study. This chapter details regarding the methods to collect and analyze data.

Sample

This study was conducted in an urban elementary school in the Central Valley of California. The school is one of 33 elementary, eight middle schools, seven high schools, and three special program schools in the district. According to the School Academic Report Card (2017), there were 543 students enrolled in the 2015-2016 school year in grades kindergarten through six. Of the 543 students, 36.3% consisted of Asian students, and 34.6% of Hispanic or Latino students. The rest of the population included 15.3% Black or African American, 4.8% were two or more races, 2.9% white, 2.6% Filipino, 1.8% Native Hawaiian, and less than 1% were American Indian or Alaska Native. This elementary school is a Title 1 school; 94.3% of the students are socioeconomically disadvantaged, over 80% are on free or reduced lunch, 34.1% are English Learners, 12.2% are students with disabilities (California Department of Education, 2015). The school became a 1:1 school during the 2015-2016 school year; every classroom has been provided with either a class set of Chromebooks, lap tops or iPads, depending on the grade level.

The participants of this study were a convenience sample of three second grade classes as well as three third grade classes. Teachers were labeled as high, medium, or low fluency gaming usage based on ranking of usage on informal discussion. See Table 1.

Table 1
2016-2017 Teacher Usage of Online Fluency Gaming

Teacher	Grade Level	Frequency of Gaming Use	Fluency Program Used
A	2	Low	Big Brainz
B	2	Medium	Self-generated fluency program
C	2	High	FASTT Math
D	3	Low	FASTT Math
E	3	Medium	FASTT Math
F	3	High	FASTT Math

In the second-grade classrooms, each individual teacher used a different fluency gaming software resource. Teacher A did not consistently use fluency gaming in the classroom, however when it was used, the program Big Brainz was implemented as a choice for students when finished with independent work. Big Brainz was a software program purchased by the district that allows students to practice automatic recall of single digit addition and subtraction facts. The goal was for second graders to be fluent in single digit addition and subtraction. Big Brainz allows students to choose their own avatar during the first login. Students are then prompted to travel through various levels and worlds to find fluency facts. Once students arrive in a specified location, facts are then displayed in a rapid manner prompting students to respond as quickly as possible. During the first level, the program assesses the students to identify known facts and typing speed. After each interval of the game, students see a display of a table of facts. Facts mastered become highlighted in green, while the non-mastered facts continue to be greyed out. Students would then be prompted to return in search of more facts to solve. Math facts presented to the students were between two and three focus facts.

Teacher B used fluency gaming daily in the classroom at a specified time of the day. This teacher used an alternative fluency program via a self-created website. Students had to choose the appropriate Speed Test form which ranged from 1-22 and received 5 minutes to complete 50 problems. All math problems were presented on the same screen. When students passed the initial 22 sets of speed tests, the process was repeated with only 3 minutes to complete the problem set. Teacher B was the lead teacher and was very comfortable with technology.

Teacher C used the Scholastic program FASTT Math. Its use in this classroom was consistent during the first two quarters but dropped off in usage later in the year due to issues with the program. In her classroom, FASTT Math was used between 2-3 days a week. FASTT Math Next Generation was part of the Scholastic package which helps students develop automaticity in recalling basic math facts (addition, subtraction, multiplication, and division) depending on which setting was chosen by the teacher. The goal of FASTT Math is for students to be fluent in multiplication and division by the end of third grade. FASTT Math presents 2-3 focus facts per lesson. The facts are repeatedly presented to the student and must be answered in a timely manner or a timeclock pops up where the solution should be. Unlike Big Brainz, FASTT Math only presents the facts to the students in groups of 60, students are not required to navigate to find facts. The narrator voice on FASTT Math spoke to the student and reviewed the fact answered incorrectly also displaying a chart to show which facts were mastered in green. All of the third grade teachers used FASTT Math, although in differing amounts.

The University Institutional Review Board approved this thesis protocol #1617-154 on June 28, 2017.

Methods

This study is a causal-comparative study of second and third grade unit achievement scores. This study was conducted using the math achievement score data from the beginning to the end of the 2016-2017 school year. Scores on the unit tests ranged from zero to 100%. Unit tests were based on the Math Expressions curriculum which the school district had adopted. These summative assessments from the entire school year could only be accessed by the principal who gave permission for the data to be used in this study. Data were then put onto an Excel document and imported to SPSS for analysis. Each of the unit tests were given at the end of each unit which could last anywhere from three to several weeks, depending on speed of instruction.

Data were also collected in the 2017-2018 school year from the 2016-17 students who were second and third graders; they were third and fourth graders in 2017-18. Examining data from the subsequent year allowed for examination of the possibility of longer-term effects of gaming fluency use and a way to compare performance over time.

The covariate of 2016-2017 SBAC Math performance scores were also exported and included in the study. During this study, all data were kept in a secure confidential location. While running tests on the data, student scores were labeled by identification numbers to protect confidentiality.

Instruments

The school curriculum was Math Expressions. Summative assessments were standardized and the same assessment was being used in each of the classrooms. Each of the unit assessments included similar posttest questions but were randomized for each of the students. Students completed the performance assessment at the end of the unit and were given a benchmark score between 1-4 on the report card, depending on the percentage correct on the performance assessment. The online tool being used to record performance assessment scores was Think Central which is a component of Math Expressions.

Data Analysis

The performance assessments were given to each student in the participating classes at the end of each unit in the 2016-2017 academic school year. Students were given as much time as they needed to complete each of the assessments. Each of the teachers used online fluency gaming in a different manner. To test the first hypothesis that students who participate in regular fluency gaming would have a higher performance score on the unit exam, an ANOVA was run on both second and third grader's scores to examine the differences in scores based on the amount of fluency gaming usage. To test the second hypothesis that second grade students who participated regularly in fluency gaming will have higher performance scores when they advance to third grade, an ANOVA was run to look for the differences in performance scores between the three classes. A similar ANOVA was run to test the impact of fluency gaming in third grade on their performance as fourth graders. For the fourth hypothesis, an ANCOVA was run to examine the differences in performance scores for third and fourth grade students using the covariate of 2016-2017 SBAC Math scores. Data were entered in the Statistics Package for the Social Sciences v. 23.0. An alpha level of .05 was used for all analyses.

Summary

This study was completed using three, second grade classrooms analyzed for fluency usage and examined whether the use of the gaming software impacted achievement scores. The study also included three, third grade classes for which data in the next grade level was also examined. A convenience sample of an urban school in California was used. The fluency programs being used were Big Brainz, FASTT Math, as well as a self-created fluency gaming site. The program Math Expressions was the curriculum being used. The achievement data were collected via Think Central, the online assessment tool for the curriculum. Results are analyzed in Chapter IV.

CHAPTER IV

RESULTS

This study examined the impact of fluency gaming on math achievement. It further examined whether fluency gaming in the third grade would impact achievement in the fourth grade. Results related to the research questions and hypotheses are presented.

Hypothesis 1.1

Hypothesis 1.1 suggested students who regularly participate in fluency gaming will have a significantly higher performance score on the unit exams. An ANOVA was run for both grade 2 and grade 3 student data. Results are displayed in Table 1. There was no difference in means for the grade 2 students. However, there was a difference in means for the third grade students, $F(2,60) = 8.98$, $p < .001$, $\eta^2 = .23$. Since Levene's test indicated variances were similar, Tukey's post hoc was examined. The cumulative unit assessments were significantly higher for high usage students ($M = 415.91$, $SD = 85.31$) than students that had a low ($M = 332.09$, $SD = 96.58$) or medium usage ($M = 300.76$, $SD = 93.56$) of fluency gaming. See Table 2.

Hypothesis 1.2

Hypothesis 1.2 suggested that students in second grade who regularly participated in fluency gaming during the 2016-2017 school year would have a significantly higher performance score for the first unit in third grade than students who did not use fluency gaming in the classroom regularly.

Table 2
ANOVA Comparison of Students' Cumulative Unit Assessment Performance Based on Level of Fluency Gaming Use

	n	*M*	*SD*	*F*	*p*	η^2
Grade 2				3.12	.053	.11
Low	23	453.57	115.87			
Medium	17	371.76	106.28			
High	14	436.64	81.18			
Grade 3				8.98	<.001	.23
Low	22	332.09	96.58			
Medium	17	300.76	93.56			
High	24	415.91	85.31			

An ANOVA was run to determine whether there was a difference in the mean performance score for the 2017-2018 third graders based on fluency usage. The analysis determined that there was no statistically significant difference, F (2, 45) = .89, p = .42, η^2 = .04. See Table 3.

Table 3
ANOVA of Grade 3 Unit 1 Assessment Performance Based on Level of Fluency Gaming in the Second Grade Classroom

	n	*M*	*SD*	*F*	*p*	η^2
Low	16	67.25	24.62	.89	.42	04
Medium	18	59.50	25.76			
High	14	70.86	24.69			

Hypothesis 1.3

An ANOVA was run to determine whether or not fluency gaming in the third-grade classroom had an impact on performance scores for the first unit in fourth grade. The mean unit assessment score did not differ based on fluency gaming amount, F(2,54) = .07, p = .93, η^2 = .003. The mean unit score for low fluency gaming was 68.18, medium fluency gaming 66.42, and high fluency gaming 66.67. See Table 4.

Table 4
ANOVA of Grade 4 Unit 1 Assessment Performance Based on Level of Fluency Gaming in the Third Grade Classroom

	n	*M*	*SD*	*F*	*p*	η^2
Low	17	68.18	14.39	.07	.93	.003
Medium	19	66.42	15.87			
High	21	66.67	13.82			

Hypothesis 1.4

An ANCOVA was run to examine the impact of fluency gaming used in the third grade classroom on the first unit of fourth grade using the third grade end of the year SBAC score as a covariate. The mean of students' achievement scores on the first unit assessment did not differ based on fluency gaming, $F(2,50) = 6.43$, $p = .83$, $\eta^2 = .008$. The adjusted mean for low fluency usage was 67.80, medium fluency gaming 65.20, and high fluency gaming 66.00. See Table 5.

Table 5
ANOVA of Grade 4 Unit 1 Assessment Performance Based on Level of Fluency Gaming in the Third Grade Classroom with SBAC covariate

	n	M_{adj}	*SD*	*F*	*p*	η^2
Low	17	67.80	3.09	6.43	.83	.008
Medium	17	65.20	3.09			
High	19	66.00	2.92			

Summary

In hypothesis 1.1 it was thought that fluency gaming would lead to increased student achievement scores in both second and third grade. There was no significant difference in scores for second grade students. However, a significant difference was found in third grade students. In hypothesis 1.2, it was thought that students in second grade who participated regularly in fluency gaming would have a higher unit test score in the first unit of third grade. No significant difference was found. In hypothesis 1.3, it was thought that students who participated in higher levels of fluency gaming would have a higher unit test score in the first unit of fourth grade. No significant difference was found. In hypothesis 1.4, the covariate of the end of the year third grade SBAC score was used to determine if there was a difference in fourth grade achievement. The mean achievement scores did not differ based on the amount of fluency gaming from the previous school year.

CHAPTER V

SUMMARY, DISCUSSIONS AND RECOMMENDATIONS

This study was designed to examine whether or not the use of fluency gaming in the classroom had an impact on math achievement. The participants were a convenience sample of second and third grade students for the school year 2016-2017. The unit assessment scores were gathered for both grades and used as a cumulative score of the total unit assessments. Each grade had one unit that was not tested, therefore the cumulative score included six total unit assessments. These assessments were given at the end of each unit, with date of administration depending on the pace of instruction in each classroom. To test the first hypothesis, grade 2 and 3 student scores were analyzed to see whether or not fluency gaming impacted their cumulative summative achievement scores. Among the second grade students, there was no significant difference in scores between the students who participated in fluency gaming regularly and the students who had low and medium fluency gaming usage. Among the third grade students, however, there was a significant difference in math achievement scores. The cumulative unit assessment mean was significantly higher among students who used a high amount of fluency gaming than students with low and medium usage. Another hypothesis was that students in the third grade who participated in high levels of fluency gaming would have a higher achievement score for the first unit of fourth grade. It was found that there was no significant difference in mean unit achievement score in fourth grade even when controlling for existing differences using third grade SBAC math score as a covariate.

Discussion

Hypothesis 1.1 suggested students who regularly participated in fluency gaming in their classroom in the second grade would have higher levels of achievement on their unit exams. It was found, however, that there was no difference in the cumulative unit assessments. One factor that may have influenced achievement score is how much time was spent on the unit. Each classroom moved through each unit at the pace of the instructor, regardless of whether he or she used fluency gaming software.

This variation in amount of use could also have been a factor in higher level of achievement among third grade students with high fluency gaming use that was found in the current study. Even though no significant difference was found in the second grade, it was found that there was a significant difference when it came to cumulative unit assessments in third grade. Third grade students who were in the class with higher fluency gaming usage had a cumulative unit assessment of 415.91, while low usage students had an average of 332.09 on unit assessments and medium usage students 300.76. This difference could have been due to the fluency practice that was used in the third grade classroom. The main fluency gaming used in the third grade classrooms was FASTT Math Next Generation. This software program has a narrator voice, which is not a feature of Big Brainz or the self-generated fluency game used by two of the second grade teachers. FASTT Math first gets an accurate reading of typing speed by having students type numbers as quickly as possible. After typing each number students must press the space button. After the initial typing assessment, students are then given 60 facts with a countdown button on the bottom right hand of the screen. Whichever basic arithmetic function the student is working on, a table is presented of mastered facts. Each time a student logs in he or she is able to complete up to two lessons which include 2-3 focus facts each. The lessons are presented in groups of 60 facts which are rapidly presented to the students. The narrator voice guides students as to which facts are the focus. It is possible that in order for FASTT Math to have influence in achievement it must be used as recommended by the program developers. The recommended use according to the trainer was 60 minutes per week. The scores of students in the high use classroom were significantly greater than scores of students in the other two classes, suggesting the amount of use may be critical to student performance.

As part of FASTT Math lessons, students are also taken to a game page where they can play an arithmetic game which again consists of more fluency practice where basic facts must be answered as quickly as possible. According to Jackson et al. (2009), software that provides immediate feedback is effective. Programs like FASTT Math focus on a certain number of facts at a time and give immediate feedback. With enough use, this feature of the program has the capacity to increase mastery of facts.

The difference in achievement might also be due to the digital resources aligned with the unit assessments. The online component of the Math Expressions curriculum is accessed through a website called Think Central. Practice tests were available for each unit and were to be used at the discretion of each teacher. Some teachers may have utilized this resource more than others, giving the students varied amounts of practice when it came time to taking the actual unit assessment

The design of the study included a convenience sample of third and second grade students. One factor that could have influenced achievement is the initial placements of students. Classes are not divided based on achievement level of the students. Although each student participated in the same assessments as their peers, time spent on the units varied depending on the teacher. Some teachers might have spent more time on certain units, or spent a greater time reviewing before a unit exam. The effectiveness of each teacher's approaches might have varied for each student based on his or her needs.

Hypothesis 1.1 suggested that students in general who participated in fluency gaming would have higher performance scores than students who used fluency gaming minimally. This was only true for third grade students who participated in high fluency gaming usage. According to Piaget (1952), students ages 7-11 are entering the concrete operational stage which is why students who participated in high levels of gaming in the third grade might have done better than those in the second grade. The second grade students may not have been developmentally ready to master the facts. When Ramos-Christian et al. (2008) investigated the relationship between math fluency and cognitive ability, they found that students in the concrete operational stage had higher fluency retention rates than students who were still in the preoperational stage of development. Piaget stated that students ages 7-9 are gradually entering the concrete operational stage at which time they are able to conserve numbers (Piaget, 1952). The third grade students might have been more cognitively ready to retain their basic math facts which was aided by using software programs designed to increase retention.

In hypothesis 1.3 an ANOVA was run to see if fluency gaming in the third grade classroom had an impact on fourth grade achievement on the first unit test. The results showed that the unit assessment score did not differ based on the amount of fluency gaming received in the previous grade level. Similarly, in hypothesis 1.4 an ANCOVA was run to see if there was an impact on that first unit of fourth grade using third grade SBAC scores as a covariate. Results showed that the first unit scores did not differ based on the amount of fluency gaming in the previous year. Although it is important for students to practice basic math facts, practice may not always produce results in regards to retention. A factor that could have influenced this result was that the fourth grade students did not all take the same unit exam, nor did they have the same amount of time for the unit. Although there was a recommended district pacing guide, teachers did not always follow the pace, nor did they always follow the recommended order. Some of the fourth graders began with a unit on fractions and some began with multiplication. Each teacher might have had or used different strategies that were developed in addition to the curriculum, which might have been influenced by amount of teaching experience.

It is also possible that fluency gaming really does not impact student achievement. It could be just a small factor contributing to everyday learning. Teachers use a variety of techniques to deliver curriculum. Although fluency gaming a fun and engaging way to practice on a daily basis, retention may not be achieved solely through the process of fluency gaming.

The results of this study showed that there was no significant impact on achievement based on the previous year's fluency gaming usage. The only significant difference found showing a positive impact based on amount of fluency gaming usage was in the third grade, which was not enough to draw broad conclusions about the effectiveness of fluency gaming on achievement.

Recommendations for Further Research

In order to get a more accurate finding of how fluency gaming software really impacts student achievement it is recommended that future studies examine the effects of the new intervention resource adopted by the district in the 2017-18 academic year, DreamBox. This software program's required use is 60 minutes per week, according to the lead technology teacher. It is not solely a fluency gaming component but encompasses all units of study in grade levels 1-6. The program tracks the number of minutes per week of use which is visible to the teacher. However, in a curriculum that already has an online component, teachers are finding it difficult to integrate its use on a weekly basis. The district has various programs that can be used which have been purchased and only recommended for use, but it is not possible to know which programs are truly effective if there are so many options with recommended use on top of teaching the curriculum. DreamBox is unlike FASTT Math or Big Brainz in that it is not a fluency practice type of software program. DreamBox presents math problems from all units of study in the grade levels. Teachers are already overwhelmed by the amount of content in the curriculum that must be taught by the year's end. On top of that, students are expected to use various programs for certain amounts of times but there are no district requirements, only recommendations. A study examining the new option in addition to looking at the impact of other purchased resources would make it clearer as to which software really influences the results or if this type of resource impacts achievement at all.

In this study, the treatment was not consistent across classes and grades. It is recommended that a greater number of classrooms be included with consistency in the software being examined, perhaps at a district where there are set requirements on time spent on fluency gaming. It is difficult to say whether or not these programs really work because there was and continues to be inconsistency in use. Each teacher and classroom are unique. Without required amounts of use and devotion to one program, it is not possible to know truly if one program is more effective than another.

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