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Effective Differentiation Utilizing Technology in the Elementary Mathematics Classroom

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Table of Contents

Abstract

The achievement gap between high-achieving and low-performing students has long been documented in the United States. Little, if any, efforts have proven effective in narrowing this gap. The goal of this research analysis was to identify whether technology can be used to effectively differentiate math content for students and increase achievement, thereby closing the achievement gap in American schools. The results of the studies investigated were clear that technology can be an effective method for math differentiation and can help lower-performing students accelerate their learning, in some cases even surpassing their higher-achieving peers. Technology, when used correctly to differentiate in elementary classrooms, can be used to assist in narrowing the achievement gap. Further research studies must be done to clarify which apps provide the best differentiation and highest achievement gains for students.

Keywords: achievement gap, differentiation, inclusive classroom, math instruction

Dedication

For my dad: You always saw the best in me an encouraged me to pursue my dreams. I am forever grateful for your example of unwavering faith and hard work, and for your unconditional love and guidance as I began this journey. I love you to Jesus and back!

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Chapter One: Introduction

The achievement gap between high-achieving and lower-performing students in American education has been researched for decades and many solutions have been implemented with limited results (Bower, 2013). Bower (2013) indicates many of the factors contributing to the achievement gap are beyond the influence of the school system and may be more a reflection of an opportunity gap between socioeconomic classes. Students who grow up in lower social classes often have less access to technology, less direct parent interaction focused on learning, and less access to academic enrichment programs (Bower, 2013 & Rothstein, 2020). Despite many of these factors being out of the school system's reach, educators are continually working to meet the needs of all of their students and help each child achieve success with state and national standards. To address and close this achievement gap, teachers must find methods to accelerate learning within the classroom.

Importance of Research

According to the National Council of Teachers of Mathematics (NCTM), achievement gaps between higher level learners and struggling students have long been an important issue in education. Although educators are aware of this gap, no progress has been made in closing it (Sparks, 2018). The NCTM analyzed the National Assessment of Educational Progress (NAEP) assessment data over the last ten years, and found the numbers of lowest performing students and highest performing students both increased significantly, further widening the achievement gap in math acquisition (Sparks, 2018). Teachers must find an effective method for increasing the pace of learning for lower-level learners to close this gap. Using technology in the classroom can help educators accelerate learning for struggling mathematicians (Azid et al., 2020; Bai et al.,

2012; Chang et al., 2015; Hulse et al., 2019; Kaur et al., 2017; Outhwaite et al., 2019; Stacy et al., 2017; Teomara et al., 2017; Volk et al., 2017; Zhang et al., 2015).

In addition, Rothstein (2020) believes the current achievement gap seen in children from differing socioeconomic backgrounds will be exacerbated by the current coronavirus pandemic. Students from lower socioeconomic classes are more likely to have parents who have not been able to work from home and assist with schoolwork during the pandemic. Furthermore, these children are less likely to have access to technology and reliable internet to connect with teachers and learning opportunities in a remote learning setting (Rothstein, 2020). These factors make it imperative for teachers to provide as many pathways to learning acceleration as they can.

Students in any given classroom have widely varying interests, backgrounds, and degrees of readiness. For instance, when beginning a unit on multiplication, a fourth or fifth-grade teacher may find some students have already mastered multi-digit multiplication and others are struggling with the basic meaning of multiplication and fact mastery. There are also students in the middle of these two groups who have a basic understanding of facts, but are struggling with the multi-step process of multiplying large numbers. Acquisition of mathematics is sequential, needing mastery at one skill level to advance to another. Mathematics teachers of all grade levels need to be continuously assessing the effectiveness of their current teaching practices and making adjustments to meet the needs of each student in their classrooms.

Differentiating instruction in mathematics requires the teacher to assess student needs and readiness for skills to be taught in the future, as well as skills taught in previous years. The teacher must then design and implement learning activities corresponding with those needs and encourage accelerated growth in those students with the most academic concerns. The use of technology may assist teachers with the process of differentiation by assessing students' current

academic level and diagnosing areas of concern. Furthermore, some technology-based programs may be able to effectively respond to student needs as they learn, reducing the workload of the teacher.

Scope of Research

The purpose of this research was to gain insight into how technology may be used to accelerate learning for students of mathematics. The author limited this research to studies done in elementary and middle school settings. While most of the studies that follow were conducted in the United States, some of them were done internationally, giving an added lens of the efficacy of using technology in classrooms worldwide. Many of the following studies also focus on one specific app or program and one specific math skill, limiting the findings from being widely generalized or applied to a broader scope.

Definition of Terms

The Achievement Gap is the academic learning gap created by students' lack of resources, parental support, race, and other factors (Bower, 2013 & Rothstein, 2020). This gap is often present before children enter the public school system and can continue to widen over the summer months and over the course of a child's education (Bower, 2013 & Rothstein, 2020).

Differentiation is what teachers do to help students meet their state standards or academic goals. Differentiation is also the process by which learning activities can be designed to address the various needs of students in the classroom to help them achieve success with their learning objectives (Heacox, 2017).

Inclusive Classrooms are classrooms in which every student is valued and taught as an individual, including students in special education, gifted students, students who struggle academically, students from varied socioeconomic backgrounds, and students of different

cultures and ethnicities. There is a high priority on a sense of belonging and building community within the inclusive classroom. Additionally, academic tasks are thoughtfully designed with students' interests, readiness levels, and individual needs in mind (Giardina, 2019).

Research Questions

The achievement gap in education leads researchers to investigate what current practices may be used to diminish the gap. In light of what is known about differentiated instruction, how shall intermediate grade level teachers effectively use technology to teach in the math classroom? In addition, can technology be used to narrow the achievement gap using differentiation? By researching the answers to these issues, professional educators can effectively teach every student in their classroom.

Summary

This paper will analyze recent research on the most effective strategies for differentiating learning in the intermediate elementary math classroom. Differentiated tasks provide all learners in an inclusive classroom with learning opportunities designed to meet their individual needs. In chapter two, the author will examine three aspects of technology-based learning in mathematics that emerged from research. The first theme was how math apps and computer-based games can increase the interest and engagement of students learning mathematics (Azid et al., 2020; Bai et al., 2012; Hulse et al., 2019; Kaur et al. 2017; Ke, 2013; Schuetz et al., 2018). Second, the studies of Azid et al.(2020), Kaur et al. (2017), Light and Pierson (2014), Rosen and Beck-Hill (2012), Schuetz et al. (2018), and Willacy et al. (2017) all found evidence that effective differentiation can be achieved using technology in the mathematics classroom. Finally, the use of technology can increase and accelerate achievement for students of mathematics as indicated by the work of Azid et al. (2020, Bai et al. (2012), Chang et al. (2015), Hulse et al. (2019), Kaur

et al. (2017), Outhwaite et al. (2019), Stacy et al. (2017), Teomara et al. (2017), Volk et al. (2017), and Zhang et al. (2015). The final chapter of this literature review will discuss insights gained from the research, application for educational professionals, and recommendations for future studies.

Chapter Two: Literature Review

The achievement gap in education has long been a challenging issue facing teachers and educational policy makers. Before the coronavirus pandemic began in 2020, Sparks (2018) had found that the gap between under-performing students and higher-achieving students continued to widen as children advanced through their school years. The current pandemic is likely to amplify this gap even further for students who were underachieving prior to remote learning (Rothstein, 2020). The following literature review will analyze the effectiveness of using technology as a resource to address this crisis.

Motivating students is the first step in effective instruction and allows for improved differentiation. Therefore, the first theme of this literature review will focus on how technology may be used to increase student engagement in the classroom. Azid et al. (2020) investigated methods for motivating students using technology. Bai et al. (2012), Kaur et al. (2017), and Ke (2013) found students had increased engagement using technology in their studies as well.

The second theme will address how technology has also been shown to provide an effective avenue for teachers to implement differentiation in the classroom. Willacy et al.'s (2017) case study specifically investigated how differentiation was achieved, through the use of apps in math instruction. Rosen and Beck-Hill (2012) developed a program designed to differentiate and found its implementation increased achievement for students. Their results were

corroborated by Azid et al. (2020), Kaur et al. (2017), Light and Pierson (2014), and Schuetz et al. (2018), who all found that technology was an effective method of differentiation.

The final theme will discuss how engaging students and differentiating tasks using technology can narrow the achievement gap for struggling learners. Bai et al. (2012), Chang et al. (2015), Hulse et al. (2019), Kaur et al. (2017), Outhwaite et al. (2019), Stacy et al. (2017), Teomara et al. (2017), Volk et al. (2017), Willacy et al. (2017), and Zhang et al. (2015) found that the use of technology to supplement whole-group math instruction and individually target skill deficits helped students increase their overall understanding of math concepts and subsequent achievement. Furthermore, Outhwaite et al. (2019), Hulse et al. (2019), and Zhang et al. (2015), saw lower-performing groups of students increase their math skills at such a pace as to surpass their higher-achieving peers, demonstrating value of technology use in math instruction. Their studies also provided encouraging evidence that the achievement gap can be narrowed or even closed through these methods.

Engagement

The first theme that emerged from research was the effect that technology use can have on student motivation and engagement. Keeping students engaged in mathematical learning is an important component to successful teaching. In order to target the specific skills students are lacking, they must be engaged and invested in acquiring these skills. Azid et al. (2020), Bai et al. (2012), Hulse et al. (2019), Kaur et al. (2017), Ke, (2013), Light and Pierson (2014) and Schuetz et al. (2018) conducted studies that point to technology-based learning as an effective means to motivate students when learning math skills.

Bai et al. (2012) found that students who used DimensionM, a 3-D modeling game, to practice math were more motivated to continue learning math in the future than students who had

not used the program. This quasi-experimental study was conducted over 18 weeks among 445 eighth grade students from a variety of ethnic, gender, and socioeconomic backgrounds in the southeastern United States. Researchers placed participating classrooms into a control group or experimental group. Measures were taken to ensure that other variables (i.e. access to textbooks, access to computer lab, instructional methods, and content) were as similar as possible, with the experimental group receiving supplemental instruction through playing DimensionM. The control group received supplemental instruction from the teacher. Furthermore, the game was closely aligned with school-wide algebra standards that were already being taught as part of the curriculum (Bai et al., 2012).

Students in Bai et al.'s (2012) study were given a pretest and posttest on the mathematics skills and a questionnaire about their motivation in mathematics at the beginning and end of the 18-week period. One of the limitations of this study was that the two groups did not have similar compositions in regard to academic achievement on the pretest. The control group began with significantly higher scores on their pretest than the experimental group. Researchers noted that the experimental group reported higher motivation levels at the end of the period, while the control group reported lower motivation levels. Using the DimensionM game kept at-risk students engaged in their learning and continued to hold their attention throughout the experimental period (Bai et al., 2012).

Azid et al. (2020) comparably found that the use of technology enhanced student motivation and willingness to study mathematics in the classroom. Participants in this mixed-methods study were sixty, year five students in Malaysia. Student progress was measured over five weeks with a pretest and posttest on fractions developed by the researchers. Participants were interviewed after the experiment and students who used the Padlet app reported enjoying a

new learning experience, had fun practicing math skills, and felt the tools were effective in helping them learn. These results were limited by not using a quantifiable scale to measure students' opinions and feelings. However, they did indicate that teaching with technology may help students view learning mathematics in a more positive manner and may keep them more engaged than more traditional methods (Azid et al., 2020).

The work of Azid et al. (2020) and Bai et al. (2012) are further supported by Ke's (2013) study observing how middle school students in the southwestern United States benefitted from and engaged with mathematics-based computer games in a tutoring program. Ke's (2013) work added another layer of depth to the previous two studies by observing the conversations students had with each other regarding math. These 64 students participated in a mixed-methods study centered on two tutoring sessions lasting one hour each, over the course of five weeks. Thirteen of these participants attended a rural school, with the remaining 51 participants coming from a low-performing urban school. The seven tutors for these sessions were trained in tutoring methods, in addition to having backgrounds in education. Ke (2013) noted that 95% of participants found the mathematical computer games engaging and fun to use. The observations conducted by researchers also revealed interesting aspects in student behavior. Students were more likely to understand a mathematical concept and put it into practice correctly within the game when they had a short session with the tutor before beginning the game. It seemed that after they had begun playing, tutoring conversations were less effective, possibly due to students trying to multi-task. Another behavior observed were the mathematical conversations between students without a tutor present. Students would often ask one another about how to solve problems and give explanations to others. Examining conversations between the tutors and students showed that using less formal mathematical language and allowing students choice in

which game to play or which skill set to focus on, improved student engagement and their ability to verbalize their mathematical thinking. The students attending the rural school showed significant gains on state testing in mathematics, however, the majority of participants attending the urban school did not have significantly higher test scores (Ke, 2013).

In contrast with the research done by Bai et al. (2012), Azid et al. (2020) and Ke (2013), Schuetz et al. (2018) had conflicting results when examining the motivation and engagement of students while using technology to practice math. The researchers conducted a mixed-methods study using a pre- and post-engagement questionnaire with 93 second grade students in a high-achieving Oregon school district. They observed the impact of using IXL, a technology-based math intervention. Two experimental groups were formed and students in both groups received direct instruction from the teacher during the eight weeks of the study. One group received IXL intervention during the first four weeks of the study and the other received IXL intervention during the second four weeks of the study. While students were not receiving IXL interventions, they did paper-pencil interventions in the classroom, so both groups spent the same amount of time practicing the math skill (Schuetz et al., 2018).

The results of Schuetz et al.'s (2018) study found that the use of IXL had no direct impact on student engagement, according to students' questionnaire results. Conversely, qualitative results from teacher observations found that while students were engaged during both intervention times, using IXL made students more independent, more motivated, and more excited to use IXL than the paper-pencil activities. Furthermore, teachers agreed that IXL was an effective way to differentiate for students, because it provided more practice for struggling students, a reading feature allowing struggling readers to focus on the math skill, and immediate and corrective feedback. Overall, both interventions kept students engaged, but IXL provided

quicker feedback for students and they were able to work much more independently. Teachers also noted that they felt IXL was extremely beneficial for fluency and repetitive skill-building practice. However, they felt it would be less useful when working on critical thinking or problem-solving tasks because the nature of solving these kinds of problems is not based on memorization of skills. This study was limited demographically by only including participants in a high-achieving school. Researchers could expand this study to see if results are similar with a more diverse student population (Schuetz et al., 2018).

One of the school populations most needing effective differentiation and acceleration of skill development are students with learning disabilities. Kaur et al. (2017) conducted a study with students identified as having a learning disability and found that students were observed to become more independent and curious about their math development while using math apps. Motivation was seen by teachers to be a key factor that underwent a major change during this study. Initially, students were reluctant to engage, but after using the apps students became enthusiastic about both using the apps and solving math problems in general. Hulse et al. (2019) also found that a game-like features kept students absorbed in their learning, even when need to retry problems they had answered incorrectly, leading to higher academic achievement. Further results of these studies will be discussed in the following sections.

The inquiries made by Azid et al. (2020), Bai et al. (2012), Kaur et al. (2017), Ke (2013) and Schuetz et al. (2018) all found evidence that technology can have a motivating effect on children's ability to learn and practice math skills. As previously stated, the achievement gap in education results from children entering the public school system already at a disadvantage academically. Teachers can use technology resources to engage their struggling students and provide differentiated tasks tailored to their learning needs to help narrow that gap. The next

section of this paper will delve into how differentiation can be achieved through the use of technology in the classroom.

Effectiveness of Differentiation

The second theme to develop during research was the importance of differentiating learning activities while utilizing technology in the classroom. This portion of the literature review will explore the effects of using technology to differentiate math instruction. Targeting skill sets for students and individualizing the learning experience was a significant component of technology use (Azid et al., 2020; Kaur et al., 2017; Light & Pierson, 2014; Rosen & Beck-Hill, 2012; Schuetz et al., 2018; Willacy et al., 2017). The previously mentioned study in Malaysia utilized components of differentiated instruction by employing an app that allowed teachers to assign specific tasks to students, providing a unique experience for each child that was suited to their academic level (Azid et al., 2020).

Willacy et al. (2017) conducted a qualitative exploration of the use of mobile technology in assisting teachers to personalize the learning experience for individual children. Unlike the other studies researched, this team did not seek to find if differentiation with technology would improve math skill mastery. Their aim was to clarify *how* technology can be used to offer differentiated instruction for students in a classroom setting. The researchers collaborated with three teachers in a New Zealand primary school. In one classroom, two of these teachers co-taught year five and year six students, who were provided with an iPad for one-to-one technology use. The third teacher, in a year four classroom, asked students to provide their own device (Willacy et al., 2017).

Videos were taken four times during the school year and analyzed by Willacy et al. (2017), along with the teachers themselves. The team identified four general themes from their

observations: teacher-directed learning, customizable features, workplace selection, and student-led learning. Teacher-directed learning occurred when teachers were able to assess an individual student's mastery of a given skill and then direct that student to an app or activity within an app to continue practice or extend the child's learning. Teachers were also able to send digital worksheets to individual students to meet their needs. Customizable features within certain apps allowed students to present their work in various formats and colors, utilizing images and recordings to showcase their learning. Another personalization in using mobile technology was the ability of students to choose their workplace. All three classrooms had been designed to allow for student choice in seating. Students were observed sprawled out on the floor, on beanbags, at high and low desks, and on bench seats. In this way, students could choose to sit alone to complete work independently or sit near a partner to collaborate. The final theme found in observations were instances where students were asked to show the use of a strategy with a partner and make a video demonstrating the skill, including which problems the students thought would best display their learning. The researchers acknowledged the limitations of conducting this study with a small group of teachers (Willacy et al., 2017). Furthermore, the demographics of the teachers and students were not described clearly. Additional research would need to be conducted to determine if these findings can be generalized to a wider population, and if the strategy of personalization increases achievement and mastery of skills for students.

Rosen and Beck-Hill (2012) also advocated for the use of technology to individualize classroom learning experiences for children. However, their focus was to discover the extent to which differentiation can improve academic achievement. Time To Know is a technology-based math and language arts curriculum designed for fourth and fifth grade students by Rosen and Beck-Hill (2012). The program required one-to-one technology and was utilized in the classroom

to facilitate class discussion and allow for individualized learning. Their approach focused on student discovery for learning with the teacher acting as a facilitator, rather than the teacher being perceived as a direct instructor (Rosen & Beck-Hill, 2012).

The Time To Know program was implemented in classrooms to great effect (Rosen & Beck-Hill, 2012). Findings indicated that compared to control groups, students receiving this instruction were more likely to attend school regularly and had decreased disciplinary issues. Furthermore, teachers were able to increase their one-to-one interaction rates with students and modify instruction based on student feedback in the experimental classrooms.

Light and Pierson (2014) similarly found that Chilean teachers using Khan Academy were better able to differentiate instruction for their students with technology. Researchers sought to understand how Khan Academy was being integrated into existing math classrooms and to gain insight from qualitative observations and interviews with participants. Khan Academy is a free web-based program that provides skill practice for students. Teachers can use this resource to assign specific work for students or for students to choose their own learning path. Eight teachers, six administrators, and 32 students from five different schools were selected to be interviewed for this case study. Additional observations were made in 25 classrooms, some using Khan Academy and some not using it, ranging from fourth to twelfth grade. Chilean teachers using Khan Academy seemed to shift from a direct instruction approach to an instructional coach or facilitator role. When Chilean students worked on Khan Academy, they were assigned topics by the teacher or given a choice to work on their weakest skill sets. The teachers circulated, providing feedback and assistance where needed, continuously throughout the session. Student conversations in these classrooms were different than conversations heard in more traditional settings by the observers. Students could not give another child the answer to a

completely different problem than their own. Instead, they needed to explain mathematical procedures. When students answered incorrectly, they had a variety of options to get assistance within the program or from a teacher. The use of Khan Academy to differentiate learning was effective in allowing students to work at their own pace and self-direct their learning in some instances (Light & Pierson, 2014).

Kaur et al. (2017) likewise found that the use of iPads in addition to regular math instruction related to higher academic performance. Students with learning disabilities also showed improved engagement and independence. Teacher candidates in this study used a variety of math apps to tutor children with specific learning disabilities who were struggling in math. The teacher candidates designed and taught a short lesson reinforcing the concepts being taught during the large group math class. Students then used a specific app to practice that concept (Kaur et al., 2017).

Teacher candidates reported that using the apps gave specific guidance for problems that were answered incorrectly, providing a path for the adult to explain how to solve the problem. Direct feedback and the ability to earn points in some of the apps was highly rewarding for the students as well. Teacher candidates also noted how different apps were tailored to different learning styles as they included audio, visual, and tactile components. Teacher candidates cited how well they were able to individualize instruction for students using the apps. For students who grasped concepts quickly, they were able to design a more challenging learning path. Conversely, for students who struggled, the teachers could break down the concept into smaller steps and scaffold learning (Kaur et al., 2017).

One drawback of this study was the small population of students that participated, making it difficult to generalize results. It did, however, indicate that the study could be

replicated with a larger population of students in an attempt to gain a broader understanding of the effects of using math apps to further math understanding.

The previously cited study by Azid et al. (2020) found that while both the control and treatment groups increased in their knowledge of fractions, the treatment group made significantly higher gains. They also showed more mastery of the subject, indicating that the practice of differentiating tasks may help students accelerate their learning to close the achievement gap in math. Azid et al. (2020) noted that using the Padlet app, teachers were able to assign specific tasks to students to meet their learning needs, enhancing academic growth for each student. These findings support the idea that strategic, teacher-directed use of technology can help struggling students make the gains needed to succeed at grade level (Azid et al., 2020).

The work of Azid et al. (2020), Kaur et al. (2017), Light and Pierson (2014), Rosen and Beck-Hill (2012), and Schuetz et al. (2018) all clearly show that technology can be effectively used to achieve differentiation in the classroom and would subsequently assist teachers to close the achievement gap. While Willacy et al. (2017) indicated that differentiation can be accomplished by using technology and teachers indicated that differentiating was easier, they did not prove that differentiation made an impact on student learning. The ultimate goal of differentiation is to create tasks that will improve student achievement (Heacox, 2017). Accelerating student achievement is a crucial component in closing the achievement gap.

Achievement

As shown by the research, engagement and differentiation are two key factors influencing math achievement for elementary students. Azid et al. (2020), Bai et al. (2012), Chang et al. (2015), Hulse et al. (2019), Kaur et al. (2017), Outhwaite et al. (2019), Stacy et al. (2017), Teomara et al. (2017), Volk et al. (2017), and Zhang et al. (2015) all found evidence within their

research to justify using technology to teach or supplement math instruction as an effective means for increasing achievement.

In *Addressing the Math-Practice Gap in Elementary School: Are Tablets a Feasible Tool for Informal Math Practice,* Stacy et al. (2017) suggested that math practice using tablets can assist in the development of math skills for children. They found that the process of learning math in the elementary setting was more abstract and required a much larger amount of practice to achieve proficiency than reading. In addition, their research indicated more emphasis is placed on reading development from a very young age than on math development (Stacy et al., 2017).

Stacy et al. (2017) conducted research among families within a low socio-economic group in a variety of settings. While Schuetz et al.'s (2018) study using IXL focused on using IXL independently in the classroom, Stacy et al. (2017) paired children with a caring adult to use the program to practice math. Children in this study were a variety of ages and had large differences in skill readiness. The researchers found that students enjoyed using the tablets to practice math and often cited using IXL as 'fun' or 'super fun.' They also noted that students' math skills were progressing and that standardized test scores validated their findings. One of the challenges in utilizing IXL outside of the classroom was that students perceived the practice as unrelated to their math homework. The researchers also remarked on the lack of intrinsic motivation linked to math development. Students did not seek out IXL independently to practice math for the sake of improving their skills. (Stacy et al., 2017).

Stacy et al.'s (2017) study used IXL, a math program that is not set up in a game-like format. Hulse et al. (2019) conducted a study among 185 second grade students in Massachusetts using From Here To There: Elementary (FH2T:E), a tablet game. This quantitative study sought to understand if the game could help students develop problem solving strategies and algebraic

thinking. The research team specifically designed their study to find if features of a game (levels, point rewards for correctness, varying colors, and bonuses) could increase student learning. Students in the experimental group practiced math expressions with the FH2T:E game, while students in the control group practiced the same expressions without any of the game-like features for 20 minute sessions over four days. Growth was measured using a pretest and posttest aligned with Common Core Standards (Common Core State Standards Initiative, n.d.). Students who played the game were more likely to show larger gains on the posttest than students in the control group. Furthermore, students who earned lower scores on the pretest solved more problems in the app by spending time retrying the problems. They later achieved higher scores on the posttest, displaying greater gains than students who initially scored higher (Hulse et al., 2019). While this study was limited by the short time-frame, the research done by Hulse et al. (2019) indicated that a game-based approach to learning mathematics engaged struggling students and helped them narrow the achievement gap.

Another study further supporting the results of Hulse et al. (2019) and Stacy et al. (2017), was conducted by Outhwaite et al. (2019) within the early elementary classroom setting in the United Kingdom (U.K.). This qualitative study found that the use of math apps significantly increased students' learning, compared to peers who did not use the apps. Students participating in the study were placed in one of three groups. The first group was a control group that received whole-group math instruction and small group math instruction, which is the norm in the U.K. The second group received whole-group instruction and used math apps in replacement of small group math instruction. The third group received whole and small group math instruction, and additional time using math apps. The third group was found to have made three to four months of additional progress compared to students in the control group, while students in the second group

were found to have made two additional months of progress compared to the control group. A key finding from this research is that the more time students spent practicing math through various means, the more progress was made (Outhwaite et al., 2019).

Similarly, Chang et al. (2015) developed a math video game called The Math App to develop intermediate elementary and middle school students' understanding of fractions. The Math App requires students to move through five levels of increasing complexity, while dividing chocolate bars into correct fractional pieces for virtual customers. The researchers developed a quasi-experimental study to determine to what extent the video game would improve proficiency in math and if those effects were different for students among varying proficiency levels. Participants in this study were 77 sixth grade students, 133 seventh grade students, and 96 eighth grade students in southwest Virginia, divided into control and experimental groups by class. Students had been placed by the school into inclusion, regular, and advanced classes prior to the study being conducted. Inclusion classes were comprised of students needing special help and students performing at grade level. Regular classes were made up of students learning at grade level, and advanced classes had high performing students (Chang et al., 2015).

All participants were given the same pretest and posttest written by Chang et al. (2015). No information was given in the study to determine the validity of this assessment. Students then practiced fractions for 20 minutes over the course of 18 days. The experimental group practiced using The Math App, while the control group practiced the same skills using paper and pencil. Results showed significant gains were made by students across proficiency levels who used The Math App, compared to students who practiced using paper and pencil. In fact, the control students in the regular and advanced classes had decreased proficiency

on the posttest. Additionally, students in the inclusion group benefited significantly more from playing The Math App than did students in the regular and advanced classes (Chang et al., 2015).

The authors of this article did not dictate any limitations. However, the experiment was conducted by the same team that developed the game used within the study. Conducting a study using The Math App independently of Chang et al. (2015) would lend further credibility to their findings and limit the perceived potential for bias. An additional study may also allow generalizations to be made regarding probable outcomes for students of varying proficiency levels who use this program as an intervention.

Zhang et al. (2015) conducted a similar month-long study in the southwestern United States with 18 fourth grade students using Splash Math, Motion Math Zoom, and Long Multiplication math apps. Their results validate the findings of Chang et al.'s (2015) study. The goal of Zhang et al's (2015) research was to find out if the use of math apps would improve student learning in math, with a focus on results for struggling students. All students in the classroom participated in using the math apps, but were separated into groups based on learning level when analyzing data. Students took pre and posttests in three different areas of math: place-value in decimals, comparing and ordering decimals, and multi-digit multiplication. Each app listed above was used for the corresponding math skill during instructional time. In each of the three post-assessments, students showed improvement. The group of struggling students made larger gains than the at grade level student group, narrowing the achievement gap. These results, although limited by a small participant size, indicated that math apps can be used with struggling students to accelerate their learning and help them reach the skill levels of their peers (Zhang et al., 2015).

Teomara et al. (2019) studied the effects of computer-based math interventions on students' self-beliefs related to mathematics. Their research focused on how a child's initial self-belief regarding a math activity, whether they believe they will succeed or not, affects their ability to learn. This study utilized the ST math program, which used a game-style format where students began with a basic concept and as they leveled up, the content was scaffolded, becoming increasingly complex. When students answered incorrectly, they were shown the correct way to complete the task (Teomara et al., 2019).

Students in the study conducted by Teomara et al. (2019) were from 52 different schools in California, ranging from second to fifth grade, the majority of which are English Language Learners and have free or reduced lunch status. Participants were given a self-efficacy survey prior to using ST math for the school year. At the end of the year, students reported higher levels of positive self-belief in their ability to solve mathematics problems. Using the ST math program, students who were initially struggling in math reported much higher self-beliefs at the end of the study. Students who reported high self-belief at the beginning did not show as large of a gain in self-efficacy (Teomara et al., 2019).

Regarding math performance and skills gained from use of the ST program, the researchers were unable to specifically correlate the use of the program and its effects on self-belief to higher standardized test scores (Teomara et al., 2019). The ST math program had been previously determined to have a small positive effect on standardized test scores, so it was unclear whether the gains made by students were related to their positive self-beliefs or use of the program (Teomara et al., 2019). These insights indicated that other computer-based math programs could be used to build self-efficacy in students. Utilizing a different program may yield

different results in academic performance, as indicated by the studies of Outhwaite et al. (2019), Stacy et al. (2017), and Rosen and Beck-Hill (2012).

Volk et al. (2017) conducted a study over seven months with 12 Slovenian third grade classrooms to find the impact tablet use can have on cross-curricular learning. The 12 classrooms were divided into two groups. The experimental group used tablets and apps designed by the researchers to align with instructional goals to promote cross-curricular studies of math, science, and the Slovene language. The control group used traditional paper-pencil activities to learn the same content. Students using the apps were found to be more persistent in completing cross-curricular tasks than students using paper-pencil. App use kept students motivated and gave immediate feedback to prevent students from repeating mistakes. It also allowed teachers more time to assist struggling students, as stronger students were kept engaged with higher level tasks in the app. At the end of the study, students who had used apps showed significantly higher achievement in tasks that required procedural and problem-solving knowledge than those who only used paper-pencil. Researchers inferred app use helped students to frame their knowledge and apply it across contexts. They also concluded that students who had not used the apps were more likely to compartmentalize or separate their math knowledge from other content areas. Tablet use also made it possible for students to move around the classroom and into positions more comfortable for learning (Volk et al., 2017).

The study done by Rosen and Beck-Hill (2012) also found that their Time To Know program led to increased student performance on the Texas Assessment of Knowledge (TAKS) standardized test. There is a clear consensus among the research that technology can be an effective means to help students master math skills (Azid, et al., 2020; Chang et al., 2015; Hulse et al., 2019; Outhwaite et al., 2019; Stacy et al., 2017; Volk et al., 2017; Zhang et al., 2015). One

of the key components of these studies was also the direction of the teacher or other knowledgeable adult to select the appropriate app or game and tailor the learning experience for the child.

Furthermore, the research of Hulse et al. (2019), Chang et al. (2015), Zhang et al. (2015), Bai et al (2012), and Outhwaite et al. (2019) point to differentiated technology use as an effective method to narrow or even close the achievement gap. In Bai et al.'s (2012) previously mentioned study using the DimensionM game, the control group began with significantly higher scores on the pretest than the experimental group. However, students in the experimental group showed significantly higher academic gains than the control group, effectively narrowing the achievement gap between the two groups. Increasing the gains made by struggling students is imperative to reducing the achievement gap.

Review of the Proposed Problem

The achievement gap between low-performing and high-achieving students has long been a serious issue facing educators. The coronavirus pandemic has increased teacher workload and made this gap larger for student who have less support at home and less access to technology. Teachers must find creative ways to help accelerate the learning of their struggling students to make progress in closing this achievement gap.

Importance of Research

Closing the achievement gap is imperative for teachers and students alike. The gap in achievement has remained unchanged for years and continues to grow for students of color, students from lower socioeconomic classes, and for students who have had less access to remote instruction during the pandemic. Without changes to the way teachers and policy makers address this problem, it will endure for years to come.

Summary of Findings

This literature review sought to understand how intermediate grade level teachers might employ technology to effectively differentiate within their classrooms and work to narrow the achievement gap. The research clearly shows a connection between the use of technology and improvement in math knowledge for students. Engagement and motivation, differentiation and higher achievement can be the result of using technology properly in a classroom setting.

Teachers remain the focus of how to make this differentiation effective and increase academic achievement. In many of the studies analyzed, the teachers made decisions about who would practice which skill and if they would work in groups or individually, what app might be used to relate to content being taught, and where students would use the technology available to them. Additionally, teacher interaction with students before beginning technology use or during the use of technology to clarify and redirect made an impact on how well students understood the material.

Conclusion

Research clearly shows that proper use of technology to supplement math instruction can have a positive effect on student achievement. Several researchers found technology use to be a successful method for helping lower-performing students master skills and achieve at least as well as, or even higher academic gains than their peers. Teachers can benefit from this research by thoughtfully and intentionally incorporating technology into their classrooms to help differentiate instruction and accelerate learning to close the achievement gap.

The final chapter of this paper will offer insights gained from this body of research, applications that can be made for current teachers or future educators, and suggest recommendations for future research.

Chapter Three: Discussion, Application, and Future Studies

In the final portion of this paper, the author will discuss insights gained from the research, practical application for educators, and recommendations for further investigations into technology as a teaching tool. Technology is continually changing as new apps and programs are developed. The results of the research contained in this study will no doubt be expanded upon in the years to come. Continual evaluation of resources and best teaching practices will be necessary to help educators make informed decisions about how to best utilize technology within their classrooms.

Insights Gained from Research

From the studies analyzed in this literature review, several insights into the best uses of technology to supplement math instruction can be made. There are a vast number of apps and programs that can be used to supplement math instruction, making it difficult for teachers to decide which may provide the best results for students. There is also a lack of peer-reviewed, scholarly studies that focus on the ability of math apps to effectively differentiate and increase achievement. Another important understanding highlighted by these studies was the crucial role of the teacher in providing differentiation.

One significant point that can be made from the research is that there are a wide variety of apps and other programs that have been designed to focus on specific skills or grade levels. It is evident that utilizing apps and other forms of technology can help students accelerate their learning and master math skills in specific areas. What was not abundantly clear from this research is what particular apps are most useful or beneficial to students. As it stands, the results of this research may be difficult for teachers to implement, as it would require a large amount of

time to examine apps and determine which may be the best fit for individual students or a particular unit of mathematics.

Another insight that can be gained from this body of research is the importance of the role of the teacher in thoughtfully differentiating for their students when using technology. Several studies point out how teachers played a crucial role in providing support before students began using technology. Students were pre-taught in every study about the content they would practice in the app or program. After children began to practice math skills with technology, teachers remained available to assist students as necessary. Several studies pointed to the teacher as playing a pivotal role in helping students clear up misconceptions and struggles they had while using technology.

Finally, one of the main difficulties in conducting this analysis of research stemmed from the lack of peer reviewed studies about this topic. There was not a large body of research to gather from, limiting the ability of the researcher to make generalizations. Without making large assumptions, these sets of data do not contain a definitive answer as to which apps may differentiate or provide the greatest acceleration of learning for students. It will be imperative for future research to be done, so that teachers can be properly educated about how to most efficiently use technology to achieve the greatest benefits for students.

Application for Instructional Practice/Educational Policies

The goal of this body of research is to be used to inform teaching practices. Many benefits can be collected from these studies, that can ultimately make a difference for teachers and students. Understanding how math apps can be used to differentiate and which apps provide the best instruction are key components to apply the knowledge gained.

The first way that teachers can benefit from this research is by conducting their own explorations of the technology that is available to them. This literature review clearly shows that apps are effective in engaging and motivating students to practice math. Additionally, results from Outhwaite et al.'s (2019) study confirm that the more time students spend practicing math, the higher their achievement will be. The drawback is that teachers will need to spend time they likely do not have on examining apps for their own use. Moreover, due to the wide variety of apps and programs available, this may be an overwhelming deterrent for teachers who want to use technology to supplement math instruction in the classroom. It is unrealistic for teachers to spend such a large amount of their little planning time on these types of explorations, which are extremely necessary to implement technology effectively. A possible solution to this problem would be for school administrators to allow teachers professional development time to do their own investigations into apps.

Second, research indicated that the teacher plays a vital role in the process of differentiating technology use for children. Teachers must thoughtfully and intentionally use technology in the classroom in order for it to be effective. It is more than handing an iPad to a child and asking them to practice math. The content students work with must be relevant to their current studies and delivered with support. When considering the use of math apps in the classroom, a teacher's differentiation would be most effective by aligning the content of a specific app to their state or national standards. Research indicates that students using technology under teacher direction, with direct feedback, can have a more individualized math experience, promoting further achievement for a variety of learners, including English Language Learners, students with disabilities, and students from low socio-economic backgrounds. This will result in helping to narrow and close the achievement gap.

While there was not a clear, one-size-fits-all app that can be used in every classroom with every age group of students, it is evident that the use of technology can be extremely effective in the classroom. Educational policymakers should advocate for the use of technology in classrooms and provide appropriate supports for teachers. These individuals could also fund and support further research into technology use for teachers. By educating teachers about the best uses of technology and the possible benefits to students, policymakers can affect change for the most vulnerable students in the education system. One unclear aspect of this research was what may happen if technology is not aligned with students' needs. Repetition of information already mastered may cause students to become bored with technology use. Likewise, students working at a frustration level may lose interest and have lower self-efficacy as a result. Having poorly trained teachers implementing technology in math instruction would likely not have the beneficial effects seen in these studies.

Recommendations for Future Studies

Throughout this research process, many gaps in knowledge were evident. There were not a wide variety of scholarly articles that had been published pertaining specifically to the research questions of the author. Many of the studies were also based upon apps or programs that had been developed by the authors themselves, making more research to validate their results necessary. Generalizable results, research into how apps differentiate to the largest effect, and studies comparing results of specific apps would give more information for teachers seeking to improve their practice of differentiation through technology.

Future research could add to this body of knowledge by seeking results that would be more easily generalized. Studies included in this literature review tended to focus on a specific strand of mathematics (i.e. fractions, geometry, multiplication, etc.) and lacked the broad scope

that teachers need to inform their practice. Some of these studies were also conducted with small populations of students, making it difficult to get a broad picture of how effective each practice might be for students across various backgrounds. Therefore, future studies should include larger groups of students and apps that incorporate more strands of mathematics. A wide scope of research would help teachers to save valuable planning time.

Another recommendation for future research is to investigate the specific apps providing the best avenues for differentiation. Many apps may provide practice of mathematical skills, but true differentiation can only be achieved when the content is matched with a student's particular needs. Not all apps and programs are designed to help students and teachers diagnose weak skill areas and provide a scaffolded path for students. This aspect is crucial for effective differentiation. Some of the programs used by researchers were noted to show students their errors, the correct way to solve them, or had a video that would explain a new topic to students as they progressed through levels. Apps like these would provide a higher level of differentiation for students, thereby increasing the effectiveness of the program.

Furthermore, additional research should be done in an effort to compare apps with one another. This information would be tremendously beneficial to teachers as it would save time in selecting apps that are appropriate for their grade level and skill area. It would also help teachers discern which apps are not worth using in their classrooms and which apps may be used to the greatest effect with specific populations of students. For example, one app may differentiate better for higher achieving students, while another may provide better supports for struggling learners. Another benefit of app comparison would be to help teachers effectively categorize apps by their strand content. Teachers would likely have better results if there were evidence-based reviews of the many math apps and programs that are available.

Conclusion

Teaching math in the elementary and intermediate grades can be especially challenging, as students may have widely varying proficiency levels upon beginning the school year. In addition, students may struggle with one mathematical skill and excel in another. Technology in the classroom setting can provide teachers with a way to give each student a different learning path, which can be built upon the student's background knowledge and skill sets. In this way, students are working to further their understanding of math concepts, increasing their ability to access the grade level curriculum.

This body of research answers the question of whether or not technology can be used to differentiate effectively for students. These studies clearly show that using technology as a means to supplement mathematics instruction has a positive effect on the engagement and achievement of learners. Achievement can also be increased for students, particularly those who struggle with mathematics acquisition, when technology is strategically used to differentiate. Moreover, it can be a successful tool to help teachers address the achievement gap crisis facing the American education system. Through using technology to engage and differentiate learning for students, teachers can accelerate academic performance and narrow or even close the achievement gap.

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