2020

Perceptions and Test Results of Spatial-Temporal Math in Middle School

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2020

Abstract

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by

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Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Education Curriculum, Instruction, and Assessment

Walden University

March 2020

Abstract

The spatial-temporal math (ST Math) technology program was developed to address mathematics deficiencies experienced by students. However, the advantages and challenges of implementing ST Math for middle school students and teachers had not been examined. This single case study of 7th and 8th grade students' performance after using the program had 2 purposes. The 1st was to ascertain teachers' and administrators' perceptions of the advantages and challenges of implementing the ST Math program. The 2nd was to see what a descriptive analysis of students' test results indicated about performance of students using the program. Vygotsky's activity theory, Mayer's cognitive theory of multimedia learning, and 21st century skills theory provided the conceptual framework. Data sources included semistructured interviews and students' test scores. Interview participants were 3 teachers and 2 administrators from a middle school in the Southern United States. Using NVivo software, interview data were analyzed via open and axial coding, and themes and patterns were identified. Student test scores were analyzed descriptively (include the tests and N). Results indicated that teachers and administrators agreed the ST Math technology program contributed to students' mathematics proficiency. Students' state standardized test scores showed fluctuation in scores for the first 4 years longitudinally, while ST Math pretests and posttests each year indicated a progression in students' learning. This study contributes to social change by informing educational leaders, educators, policy makers, decision makers and stakeholders about the usefulness of the ST Math program with 7th and 8th -grade students.

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Dedication

This study is dedicated to my late father, Capt. N. A. Ocheja, whose unending effort and encouragement has inspired me to go the extra mile to achieve this dream. To my mom, thank you for your prayers. Special thanks to my husband, Dr. Andrew Zekeri, and my son, Destiny, for their patience, support, and allowing me to take the time off to complete this program. I love you! To my siblings, especially my late sister Charity Lametu Onotu, you all motivated me to keep my head up and make the family proud. I would not forget to mention the baby of the house: Miss Rosemary Iganya Ojotu. Thank you for your prayers and for always being there for us.

Acknowledgments

I want to acknowledge Dr. Alia Sheety, who came to my rescue at a time I was going to give up. Your patience, support, and feedback has propelled me to achieve this significant result in my life. Dr. Paula Dawidowicz, thank you for your unwavering assistance and prompt feedbacks. Dr. Danielle A. Hedegard, my URR, your contribution and approval has earned me this notable accomplishment. It would have been impossible without you all. You motivated and challenged me beyond my limits. I am forever grateful.

To Dr. Wade Smith, Dr. David Bail, Dr. Amy White, Dr. Neil Blumberg, and all my professors who have impacted me with the knowledge needed to accomplish this task, I say thank you. I am also grateful to my colleagues who took the time to respond to the interview questions. You all made this dream a reality. Thank you. Above all, thanks to God almighty for granting me the grace to reach this milestone.

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Chapter 1: Introduction to the Study

Many students enter middle school unprepared for middle-school mathematics curriculum (Bowens & Warren, 2016; Chang, Evans, Kim, Norton, & Samur, 2015; Nelson, Parker, & Zaslofsky, 2016; Onwumere & Reid, 2014; Wendt, Rice, & Nakamoto, 2014); therefore, learning and mastering mathematics becomes a challenge. Teaching and learning mathematics with the assistance of technology programs have been proposed as one way to address the student achievement gap and to support students' mastery of necessary mathematics skills in middle schools (Chappell, Arnold, Nunnery, & Grant, 2015; Drijvers, 2015; Sparapani, & Calahan, 2015). Many schools are engaged in revolutionizing the learning atmosphere and developing learning proficiency by using appropriate technology tools and instructions (Onal & Demir, 2017). Because of technology usage, students are engaged in an active learning process (Colvin-Sterling, 2016; Kay, 2014; Luo, 2018; Luo, & Murray 2018; Murray & Rabiner, 2014; Nart, 2016; Williams & Larwin, 2016).

One technology program used to aid proficiency in mathematics in seventh and eighth grade is spatial-temporal math (ST Math), but its advantages and challenges have not been studied in middle school. This study aimed at learning about teachers' and administrators' perceptions of the advantages and challenges of implementing the ST Math technology program and descriptively examined what students' test results indicate about the overall changes in test scores when continuous implementation of the program is used compared to prior to its use.

The ST Math technology program is a multimedia technology game-based instructional program used in elementary and middle schools to provide students with supplementary mathematics instruction to close gaps and promote proficiency in mathematics skills. ST Math focuses on mathematics curriculum and uses game-like visuals to teach mathematics skills. Students log into their account with their picture password and complete mathematics puzzles anytime and anywhere with or without teacher assistance (Nisbet & Luther, 2014; Rutherford et al., 2014).

In this chapter, I discuss the background of the study and introduce the problem statement and purpose of the study. Also included in this section is the research questions, conceptual framework, nature of the study, definitions, assumptions, scope and delimitations, limitations, and the significance of the study.

Background

Mathematics is one of the three disciplines regularly discussed both nationally and internationally because of its importance (Brackett, 2016; Felton, 2014; Onybuchi & Norman, 2014; Sparapani et al., 2015). It predicts students' success in pursuing careers related to math or courses of study in college that will empower them to transform their lives and society (Aguirre, 2016; Çetinkaya, Özgören, Orakcı, & Özdemir, 2018; Felton, 2014; McNeil & Fairley, 2016). In other words, to be successful in science, technology, engineering, and mathematic-related (STEM) courses in high school, college, and career, middle-school students must be successful and acquire mastery in basic mathematics skills (DeCoito & Richardson, 2016; McNeil & Fairley, 2016; Nelson et al., 2016). Mathematics underachievement has been a major concern nationally (Callan & Cleary, 2018). Students' failure to master these skills early will contribute to difficulty in meeting grade level expectations in later years because mathematics skills build on one another (Brackett, 2016; Nelson et al., 2016). Unfortunately, some students enter middle school without mastering these basic mathematics skills and are not prepared for the mathematics curriculum.

Based on the importance and relevance of mathematics to students' academic and functional ability, students are expected to learn and be proficient in math. To ascertain students' level of proficiency in math, students in the United States are required to take a yearly mathematics standardized test (Polikoff, Greene, & Huffman, 2017; Stotsky, 2016). This test is vital for educators' accountability. The students' standardized tests are valuable methods for rating students learning and holding teachers, schools, and districts accountable for the failure or success of the school (Balenlyne & Varga, 2016; Polikoff, Greene, & Huffman, 2017; Stotsky, 2016). Students tend to be uninterested and unmotivated in learning the mathematics subject, which can lead to a lack of proficiency in the subject (Balenlyne & Varga, 2016; Herges, Duffied, Martin, & Wageman, 2017; Musu-Gillette, Wigfield, Harring, & Eccles, 2015).

Research indicates that integrating technology in teaching and learning will bring about a significant increase in learning achievement and improve students' proficiency in any given subject and the standardized testing associated with it (Colvin-Sterling, 2016; Kay, 2014; Luo, 2018; Luo, & Murray 2018; Murray & Rabiner, 2014; Nart, 2016; Williams & Larwin, 2016). Wu (2018) stated that technology games that are skillfully designed are beneficial and can promote and aid students' learning and understanding of the subject. Similarly, Edwards and Boody (2017) maintained that computer games increase students active learning and commitment by providing both audiovisual learning setting.

ST Math has been proposed as a multimedia technology game based instructional program that enhances students' engagement in mathematics thereby improving their mathematics proficiency. The program makes use of game-like visual to demonstrate mathematic skills. Research of ST Math usage in elementary schools has indicated it benefits students' mathematics curriculum mastery (Nisbet & Luther, 2014; Rutherford et al., 2014; Wendt et al., 2014), but there is no documented research regarding its advantages and challenges when implemented at the middle-school level.

In this study, I examined the advantages and challenges of implementing ST Math on students' learning and proficiency in mathematics in seventh and eighth grade. To accomplish this, I examined teachers' and administrators' perspectives of the program as a research-based curriculum that seeks to assist students in mathematics proficiency. I also descriptively examined what students' test results indicated about the overall changes in test scores when continuous implementation of the program is used in seventh and eighth grade compared to prior to its use. The outcome of the study may fill a gap in the literature where there has been a lack of research on the advantages and challenges of ST Math in middle schools and the benefit of the continuous use of the program (more than a 1-year period) to improve the quality of students' learning and proficiency in mathematics. In addition, the results of this study may inform and allow better understanding for decision makers about the advantages of the program and could potentially produce several positive outcomes in the domain of curriculum, instruction, and assessment.

Problem Statement

The problem is that the advantages and challenges of implementing ST Math, a multimedia technology game-based instructional program on students' learning and proficiency in mathematics has not been studied at the middle-school level.

A small number of researchers have investigated and evaluated the role of ST Math in promoting mathematics learning, but these studies were in elementary schools (Nisbet & Luther, 2014; Rutherford et al., 2014). No similar study has been conducted in middle school, and the last documented research of the ST Math program was in 2014. Rutherford et al. (2014), Schenke et al. (2014), and Wendt et al. (2014) conducted separate research on the implementation of ST Math technology program in Grades 3 through 5 in California schools. These studies focused on the application of ST Math for a 1-year period. The question that originated out of these studies is whether continuous implementation of ST Math beyond a single school year has a more beneficial effect on the students' mathematics proficiency over time due to multiple years of exposure or long-term effects after the exposure ends (Rutherford et al., 2014; Schenke et al., 2014; Wendt et al., 2014). Therefore, in the current study I sought to address the lack of knowledge on the advantages and challenges of implementing ST Math in seventh and eighth grade to improve students' learning outcomes.

Purpose of the Study

The purpose of this qualitative single case study is to examine the advantages and challenges of implementing ST Math on students' learning and proficiency in mathematics in seventh and eighth grade. To accomplish this, I examined teachers' and administrators' perspectives of the program as a research-based curriculum that seeks to assist seventh and eighth-grade students in mathematics proficiency. I also descriptively examined students' test results to determine the overall changes in test scores when continuous implementation of the program is used in seventh and eighth grade compared to prior to its use.

Research Questions

In this case study, I sought to examine the advantages and challenges of implementing ST Math program on students' learning and proficiency in mathematics in middle school, specifically seventh and eighth grade. In the study, I addressed the following research questions:

RQ1: What are teachers' and administrators' perspectives of the advantages and challenges of implementing ST Math multimedia technology game-based instructional programing on students' learning and proficiency in mathematics in seventh and eighth grade?

RQ2: What do students' test results indicate about the overall changes in test scores with the continuous implementation of the ST Math multimedia technology instructional program in seventh and eighth grade?

Conceptual Framework

Schools and educators search for ways to engage both teachers and students in technology-driven instruction. In this research, I focused on Vygotsky's (1978) activity theory, Mayer's (2001) cognitive theory of multimedia learning, and the 21st century skills theory (Partnership for 21st Century Skills, 2006). These three theories deal with the importance of technology in teaching and learning and how to successfully incorporate technology during instruction to enhance students learning and achievement in a technologically driven society. The theories contribute to making the learning process easier by creating guidelines for a conducive interactive environment where students are actively involved and are learning by doing, communicating, and receiving feedback (Kaptelinin & Nardi, 1997; Kuzu et al., 2007; Mayer's 2001; Partnership for 21st Century Skills, 2006; Redmond, 2015; Venkat & Adler, 2008; Vygotsky, 1978).

In activity theory, Vygotsky (1978) maintained that "all premeditated human actions are goal-directed and tool-mediated by artifacts or tools" (Venkat & Adler, 2008, p. 127). This study is grounded in these relevant constructs of activity theory which suggest that (a) there is an individual or collective subject who performs an action, (b) the action or activity is aimed at an object or something, and (c) there should be an interaction between the subject and the object (Venkat & Adler, 2008; Vygotsky, 1978).

The study research questions are designed to explore the advantages and challenges of ST Math as students and teachers (subjects) interact with the program using desktop computers, iPads, or laptops (tools). In this research, the object is the ST Math program. For this research, elements of activity theory are a necessary phenomenon to be studied. Interview questions were used to explore the teachers' and administrator perspectives through the lens of activity theory. I constructed the interview protocol to include the relevant constructs of the conceptual framework. My data analysis was grounded in the conceptual framework using priority codes that included the relevant elements of the activity theory.

Cognitive theory of multimedia learning (Mayer 2001; Mayer et al. 2004; Mayer, 2014) is focused on the concepts that (a) students best acquire knowledge when words and pictures are showed in conjunction instead of words alone, (b) students need the opportunity to make connections between the verbal and graphic conceptual schema construct they have created (Mayer's, 2001; Kuzu et al., 2007), and (c) working memory is the most important aspect of multimedia learning because multimedia learning takes place in the working memory (Mayer, 2014; Schweppe, 2014).

This research study was framed by the concept that instructional practices should include multimedia instruction to maximize students' mathematic learning proficiency. I used interview questions to explore teachers' and administrators' perspectives of the advantages and challenges of the ST Math program as a multimedia human computer interaction program. My data analysis was grounded in the conceptual framework using priority codes that included the relevant elements of cognitive theory of multimedia learning.

Another conceptual framework for this study was 21st century skills theory (Partnership for 21st Century Skills, 2006), which is used to focus on the following:

1. Enhancing learners' knowledge and making them successful in schools and careers (Partnership for 21st Century Skills, 2006);
2. Engaging students in multimedia projects, such as online games (Senechal, 2010);
3. Technology that enables students to acquire skills and knowledge needed to function successfully in the technological world of the 21st century (Redmond, 2015);
4. Shared responsibility of schools and educators to ensure students receive education and training that prepares them for the workforce and society (Partnership for 21st Century Skills, n.d.; Tucker, 2014); and
5. Teachers' ability to grasp students' interest as they efficiently incorporate extensive kinds of media texts into their curriculum (Redmond, 2015).

This study's research questions are designed to explore teachers' perceptions on the advantages and challenges of the implementation of ST Math as an element of the 21st century skills theory that contributes to improving students' mathematics proficiency. The study is guided by the fact that instructional practices should include elements of 21st century skills, especially technology application, which must be relevant to students' learning (Partnership for 21st Century Skills, n.d.; Tucker, 2014; Redmond, 2015). The interview questions were used to explore the benefits of continuous implementation of ST Math beyond a single school year and how, as an element of 21st century skills, it contributed to improving students' mathematics proficiency through the lens of test results. In the data analysis, I used a priori codes based on elements of the 21st century skills theory to develop the themes.

Nature of the Study

The nature of this study is a qualitative single case study that includes multiple data streams. Qualitative research is mainly investigative research that searches for in-depth understanding of a social phenomenon within participants' natural setting (Creswell, 2009, 2013, 2014; Ngozwana, 2018). Case study research is employed to analyze a phenomenon, generate hypotheses, or verify an approach (Creswell, 2009; Creswell, 2013). The phenomenon studied in this research was the ST Math program. Participants for the study consisted of three mathematics teachers, an administrator, and a school improvement plan (SIP) leadership team facilitator of Midland Middle School (pseudonym). Data collection involved participant interviews, descriptive examination of documents such as student scores on the ST Math pretest, posttest and recorded standardized test scores from the last 5 years. Inter transcripts were provided to the participants for verification and then coded by searching for themes. I used the computer software NVivo to produce code maps and organize the codes into themes. Following, I descriptively analyzed the students' test report scores. I triangulated the different data collected for trustworthiness.

Definitions

Spatial-temporal math (ST Math): A multimedia technology game-based instructional program built on mathematics curriculum and pedagogy. Students log into the program with their password and solve mathematics puzzles (Nisbet & Luther, 2014; Rutherford et al., 2014; Schenke et al., 2014; Wendt et al., 2014).

Mathematics proficiency: The ability of students to understand mathematical concepts, order of operations, and relationships between mathematical concepts (Çetinkaya et al., 2018).

Middle school: An intermediate school in between elementary school and high school. Most middle schools are comprised of sixth, seventh, and eighth grades (Çetinkaya et al., 2018; Romero, Master, Paunesku, Dweck, & Gross, 2014). The setting for this study includes only seventh and eighth grade.

Technology instruction: The use of technological tools to support teaching and learning. Students and teachers participate actively in a technology rich classroom (Colvin-Sterling, 2016; Kay, 2014; Luo, 2018; Luo & Murray 2018; Williams & Larwin, 2016).

Mathematics curriculum: The "plan for the experiences that learners will encounter, as well as the actual experiences they do encounter, that are designed to help them reach specified mathematics objectives" (Remillard & Heck, 2014, p. 707). A planned learning objective geared toward enabling students to understand mathematical concepts and relationships between them.

Assumptions

Three assumptions emerged from this research. First, during the interviews, I assumed teachers and administrators would give honest perspectives regarding the advantages and challenges of ST Math technology program in the school. Second, I assumed I would obtain reliable data from the school. Third, I assumed that the students would perform to the best of their abilities on the pretest and posttest and the state standardized test. These assumptions were necessary because they enabled me to ask the right questions, analyze multiple data, and examine participant backgrounds to determine the trustworthiness and validity of the accounts; they kept me focused throughout the research process.

Scope and Delimitations

The scope of this study was confined to seventh and eighth-grade students in Midland Middle School. I chose this group because the students participated in the ST Math program. I would have preferred only students who are not proficient in mathematics to participate, but in this case, all Midland Middle School students participated in the program. The recorded standardized test scores I examined were limited to the last 5 years, 2014 to 2018. Interview participants were three mathematics teachers, an administrator, and a SIP leadership team facilitator at the middle school. I would have preferred to interview more than three mathematics teachers, but this particular school has a small population of students and teachers. The ST Math program is related to human computer interaction theory, which was not chosen as one of the applied theories in this research. This research is restricted to this particular school, but the results may be applicable to similar situations, similar populations, and similar phenomena.

Limitations

This study focuses on a specific program (ST Math) using technology in a specific middle school; therefore, the results cannot be generalized to include other schools. Also, the results are restricted to student performance in mathematics and do not involve other subjects or the school climate. The sample size for teacher interviews was small because there were only three mathematics teachers at the school. Nonetheless, the inclusion of other forms of data collection that enable triangulation enhances the validity and trustworthiness of the research.

Significance

The outcome of this study may add to the body of literature where there has been a lack of research on the advantages and challenges of ST Math in middle school and the benefits of continuous use of the program longer than a 1-year period. In addition, the results may inform and allow better understanding for decision makers about the advantages of the program and could potentially produce several positive outcomes in curriculum, instruction, and assessment. The results may identify possible successes and gaps in the ST Math program as a solution to students’ mastery of mathematics. Wendt et al. (2014) emphasized that the strength and the efficiency of the U.S. economy and its labor force is determined by its education system producing students who have proficient mathematics skills. Similarly, Musu-Gillette, Wigfield, Harring, and Eccles (2015) stressed that belief in perceived importance of mathematics as well as ability and interest in mathematics predict students’ plan to pursue a math-intensive career or course of study in high school. Therefore, it is imperative for stakeholders to empower students to be competent in mathematics. The results of this study may contribute to a better understanding of how to support students to be proficient in math using technology.

Summary

Schools and educators search for beneficial approaches to engage both teachers and students in technology-driven instruction. Hall and Hord (2015) attested that, in this education age, various research on how to improve learning practices is being conducted. To improve students' mathematics proficiency at the participating school, ST Math was adopted and incorporated into the curriculum. Researchers have emphasized that effective technology integration into the curriculum will improve students' knowledge, keep them engaged and motivated, and provide them with the opportunity to learn through text, images, and sounds (Colvin-Sterling, 2016; Kay, 2014; Luo, 2018; Luo & Murray 2018; Murray & Rabiner, 2014; Nart, 2016; Williams & Larwin, 2016). Similarly, National Educational Technology Standards (2014) have stressed the need to use learner-centered strategies and provide students with appropriate digital tools and resources. Vygotsky's activity theory, the 21st century skills theory, and Mayer's cognitive theory of multimedia learning have contributed to enhancing and enriching schools and classrooms that have implemented them. They have served as a course of action for the implementation of efficient approaches to engaging teachers and students in technology-driven instruction and learning.

In Chapter 2, I focus on the importance of mathematics proficiency in middle school, middle-school mathematics curriculum, technology application in learning, and a description of ST Math program. Additionally, I discuss the implication of school accountability, standardized testing, teachers' perceptions, and limitations of using technology in the classroom. I also establish the conceptual framework of the study and review specific literature search strategies and terms used in the study.

Chapter 2: Literature Review

National Center for Education Statistics (2014) revealed that many middle-school students in the United States perform below average on the National Assessment of Educational Progress mathematics assessment. The assessment results indicated that students are not well-prepared for middle-school mathematics curriculum (Bowen & Warren, 2016; Nelson et al., 2016). Students' positive perspectives concerning mathematics start regressing in elementary school; at the same time, they develop an increase in math anxiety (Balenlyne & Varga, 2016). When they arrive at middle school, their attitudes decline further, and they start losing self-confidence in their mathematics capabilities (Balenlyne & Varga, 2016; Onal & Demir, 2017). Lack of success in mathematics education is a problem of national concern (Callan & Cleary, 2018; Levi, Chahine, Garrett & Wang 2016), and for more than 50 years, educational stakeholders have struggled to determine the best method of improving mathematics proficiency (Brown, 2018; Mulcaly, 2014).

School districts spend a significant amount of funds on lessons and practices to increase student proficiency in mathematics, with little success (Brown, 2018). The lack of progress has established a need for a research-based instructional curriculum that can facilitate an increase in student mathematics proficiency from below average to average and above average. Researchers have reported significant increases in student academic outcomes when technology is implemented and integrated into the curriculum (Chappell et al., 2015; Drijvers, 2015; Sparapani, & Calahan, 2015; Williams & Larwin, 2016). Technology integration in all scope of subjects has become linked to effective teaching in public schools (Park & McLeod, 2018). K-12 schools in the United States and beyond are investing in educational technology and software to promote student learning (Leonard et al., 2016; Park & McLeod, 2018). With the increasing availability of technology-based tools, such as educational software and apps, studies have shown that these tools offer new approaches and strategies for educational pedagogy (Karatas, Tunc, Yilmaz & Karaci, 2017). This technology complements the traditional classroom teaching method (Park & McLeod, 2018; Working, 2018) and changes the classroom environment by facilitating a change in the learning culture from the traditional teacher-centered paradigm to a student-centered paradigm (Levi et al., 2016). It also promotes higher-level thinking in mathematics and other subjects (Working, 2018). Technology reduces cognitive load (Falloon, 2017), enhances group work, and increases knowledge and evaluation (Working, 2018). It offers immediate feedback and improves motivation (Working, 2018). The use of technology in the classroom can support a more positive attitude toward mathematics for middle-school students (Balenlyne & Varga 2016).

Students in Midland Middle School scored below state average on the state standardized test. The school district introduced the ST Math technology program as an instructional curriculum to improve student mathematics proficiency. However, the advantages and challenges of implementing ST Math, a multimedia technology game-based instructional program, on students’ learning and proficiency in middle-school mathematics has not been studied at the middle-school level. The purpose of this study is to examine the advantages and challenges of implementing ST Math on students’ learning and proficiency in mathematics in seventh and eighth grade. To accomplish this, I examined teachers' and administrators' perspectives of the program as a research-based curriculum that seeks to assist students to be proficient in mathematics. I also descriptively examined student test results to determine the overall changes in test scores when continuous implementation of the program is used in seventh and eighth grade compared to prior to its use.

In Chapter 1, I introduced the topic, statement of the problem, purpose, and background information of the study. I proceeded to highlight the nature, significance, and implications for social change. Also included in Chapter 1 is discussion of the conceptual framework for the study and the assumptions, scope, delimitations, and limitations of the study.

In this chapter, my literature review focuses on the importance of mathematics proficiency in middle school, middle-school mathematics curriculum, application of technology in learning, and a description of the ST Math program. Also, I discuss the implication of school accountability, standardized testing, teachers' perceptions, and limitations of using technology in the classroom. I establish the conceptual framework of the study and review specific literature search strategies and terms used in the study.

Literature Search Strategies

The literature search for this study included reviewing peer-reviewed, scholarly articles available through the Walden University database, including published dissertations. The database includes ERIC, Google Scholar, SAGE Journals, Academic Search Complete, and Education Research. The U.S. Department of Education websites were also used to obtain information and copies of studies. The keywords used in searching online materials both alone and in combination were *technology application in learning, importance of mathematics, computer assisted instruction, instructional computer game, research-based instruction, middle school, teachers perceptions and perspective, middle school mathematics, computer learning theories, technology application theories, ST Math application, importance of technology, teacher and technology integration in learning, technology and student achievement, technology and mathematics achievement, relevance of mathematics in middle school, ST Math technology program, usefulness of ST Math technology program, activity theory, cognitive theory,* and *21st century skills.*

The scope of the literature review included peer-reviewed, scholarly articles published within the last 5 years. However, a few articles older than this were used to further reinforce some of the points related to the study. Over 60 full-text journals and peer-reviewed articles were sorted and used for this study.

Conceptual Framework

The conceptual framework for this study was based on Vygotsky's (1978) activity theory, Mayer's (2001) cognitive theory of multimedia learning, and the 21st century skills theory (Partnership for 21st Century Skills, 2006) The three theories deal with how to successfully incorporate technology during instruction to enhance student learning and achievement in a technology-driven society. These theories have influenced how software for learning has been developed and how it has contributed to supporting higher level thinking skill development. The theories contribute to making the learning process easier by creating a guideline of a conducive interactive environment where students are actively involved and are learning by doing, communicating, and receiving feedback (Kaptelinin & Nardi, 1997; Kuzu et al., 2007; Mayer, 2001; Partnership for 21st Century Skills, 2006; Redmond, 2015; Venkat & Adler, 2008; Vygotsky, 1978).

In activity theory, Vygotsky (1978) maintained that all premeditated human actions are goal-directed and tool-mediated by artifacts or tools (Venkat & Adler, 2008, p. 127). This study is grounded in the relevant constructs of activity theory, which suggest that (a) there is an individual or collective subject (agent) who performs an action, (b) the action or activity is aimed at an object or something, and (c) there should be an interaction between the subject and the object. In other words, the subject (agent) should be interacting with an object (Venkat & Adler, 2008; Vygotsky, 1978).

The research questions were designed to explore the advantages and challenges of implementing the ST Math technology program as subjects (the students and teachers) interact with the program using tools (a desktop computer, iPad, or laptop). In the classroom, the objects that the teachers interact with are the technology devices (tools) that they implement to develop the students' abilities to reason intelligently (Russell & Schneiderheinze, 2005). In this research, the object is the ST Math technology program. Constructing knowledge is an important part of students' classroom response and interaction. Technology usage in the educational environment supports and enhances the student learning abilities. For technology to be used effectively, it must be used in conjunction with existing tools and concepts in a specified environment (Russell & Schneiderheinze, 2005).

The purpose of this qualitative single case study was to examine the advantages and challenges of implementing ST Math on students' learning and proficiency in mathematics in seventh and eighth grade. To accomplish this, I examined teachers' and administrators' perspectives of the program as a research-based curriculum that seeks to assist students in mathematics proficiency. I also descriptively examined test results indicating the overall changes in students' test scores when continuous implementation of the program is used in seventh and eighth grade compared to prior to its use.

This research purpose is supported by the concept that improving students' mathematics proficiency should involve students' interaction with the ST Math technology program. Because of the interaction of the subjects with the mediating artifact—the ST Math technology program carried out on technology devices—there is bound to be changes in their learning as they develop higher-order thinking abilities that offer them the chance to build adequate knowledge that will assist them in responding intelligently to current and related issues. For this research, elements of activity theory are a necessary phenomenon to be studied. Interview questions explored teachers' and administrators' perspectives on the advantages and challenges of implementing the ST Math program on seventh and eighth-grade students' learning and proficiency in mathematics. Also, I descriptively examined test results to determine overall changes in student test scores when continuous implementation of the program is used in seventh and eighth grade compared to prior to its use. The interview protocol was constructed to include the relevant constructs of the conceptual framework. Data analysis was grounded in the conceptual framework by using priority codes that included the relevant elements of the activity theory.

Activity Model Triangle

Vygotsky (1978) demonstrate the view of subject-tool-object in his renowned triadic, shown in Figure 1 and Figure 2. In Figure 1, the triangle includes the subject, tool, and object; in Figure 2, the triangle is expanded to include the outcome of the process.

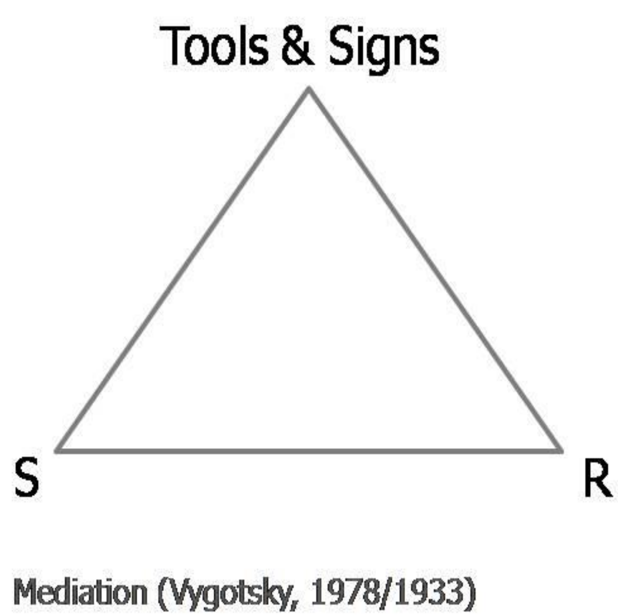


Figure 1. Vygotsky's mediational triangle (on the basis of Vygotsky, 1978/1933) Adapted from "Signs and Codes in Early Childhood: An Investigation of Young Children's Creative Approaches to Communication," by K. Guo, and N. Mackenzie, 2015, *Australasian Journal of Early Childhood*. 40, p. 2

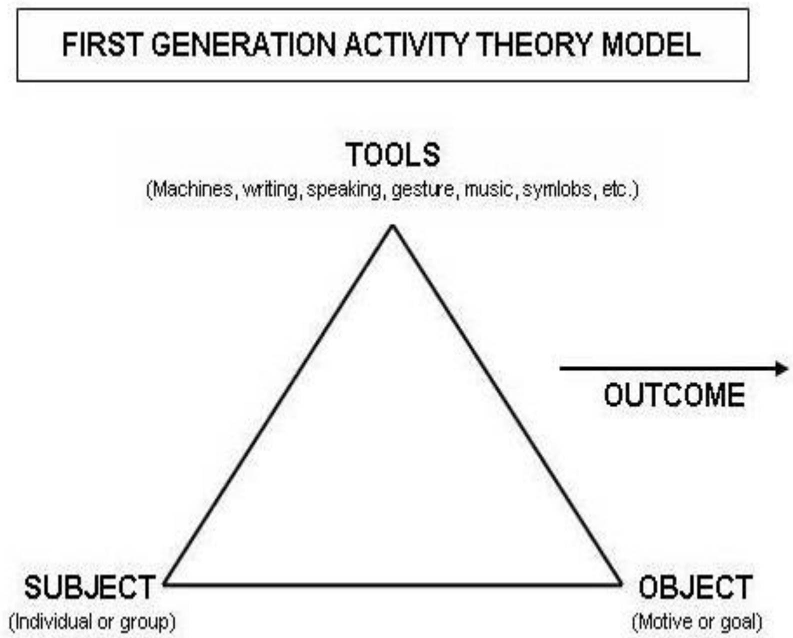


Figure 2. Model of mediated action (on the basis of Vygotsky, 1978). Adapted from "Expanding the Foci of Activity Theory: Accessing the Broader Contexts and Experiences of Mathematics Education Reform," by H. Venkat, and J. Adler, J. 2008, *Educational Review, 60(2*), p.129.

Many researchers have modified Vygotsky's triangles, including Leontiev (1981). Expanding on Vygotsky idea, Leontiev broadened the concept to include collective and institutional activities of community, division of labor, and rules. Engestrom (1987) represented Leontiev's idea in a detailed triangular outline, represented in Figure 3.

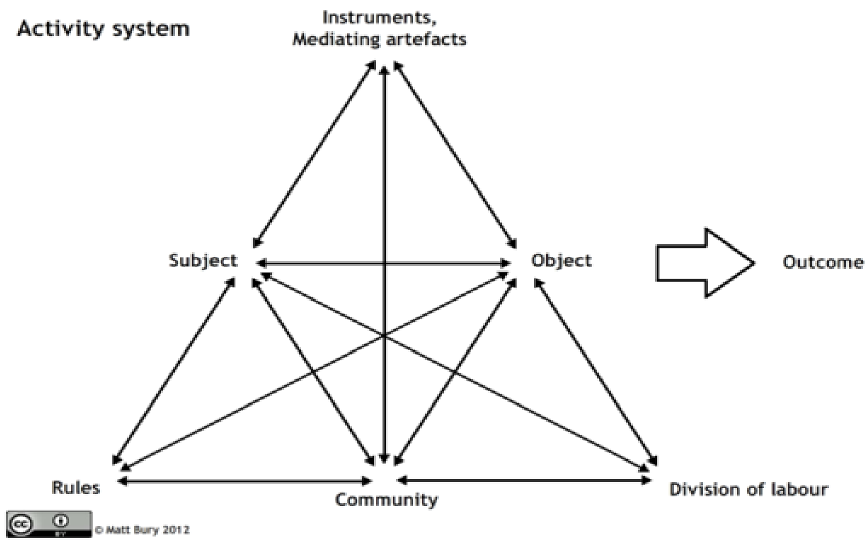


Figure 3. Model of an activity system (on the basis of Engestrom, 1987). Adapted from "Expanding the Foci of Activity Theory: Accessing the Broader Contexts and Experiences of Mathematics Education Reform," by H. Venkat, and J. Adler, J. 2008, *Educational Review, 60(2*), p.130.

Cognitive Theory of Multimedia Learning

Mayer's (2001) and Mayer et al.'s (2004) cognitive theory of multimedia learning focuses on the concept that (a) students best acquire knowledge when words and pictures are showed in conjunction instead of with words alone, (b) students need the opportunity to make connections between the verbal and graphic conceptual schema construct they have created (Mayer, 2001; Kuzu et al., 2007), and (c) working memory is the most important aspect of multimedia learning because multimedia learning takes place in the working memory (Mayer, 2014). Kuzu et al. (2007) define multimedia as computer-based applications where learners are presented with information through diverse kinds of media (Kuzu et al., 2007). Mayer (2001) summed it up as the presentation of learning material using both words and pictures. The words could be spoken or written, and the pictures are visual representations, such as animation, photos, video, or illustrations. The key purpose of multimedia learning theory as a classroom instruction strategy is on how to assist learners in mastering the learning material.

In line with the cognitive foundation, Mayer focuses on the sensory memory, working memory perception, attention, and long-term memory (Mayer, 2005; Schweppe, 2014). According to Mayer (2014), working memory is the most important aspect of multimedia learning because learning with the aid of multimedia occurs in the working memory. When pictures and words are presented to the learner through a multimedia presentation, they are processed along two distinctive channels: the ears and eyes. They then enter the sensory memory (Mayer, 2005; Schweppe, 2014). In the sensory memory learners decide on words and images to transfer to the working memory. The words and images transferred to the working memory are organized into a verbal and pictorial model, and only a small amount of information can be processed at any given period. A combination of the learners' prior knowledge and the verbal and pictorial models are retrieved from the long-term memory (Mayer, 2005; Schweppe, 2014). Mayer (2001) illustrated his cognitive theory in Figures 4 and 5 below:

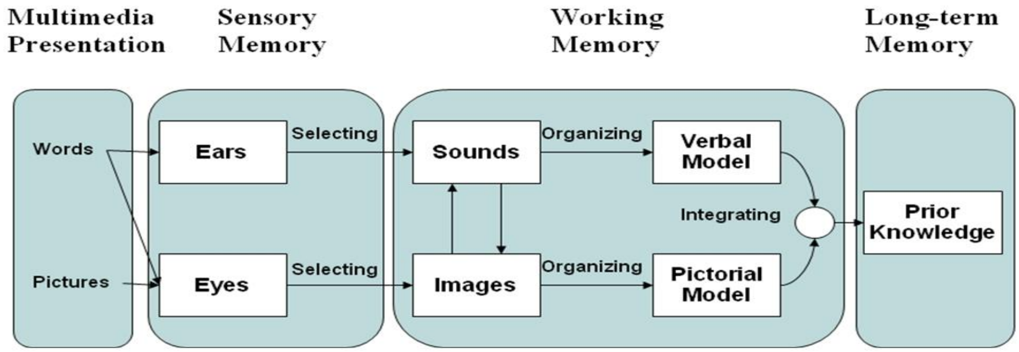


Figure 4. Mayer's cognitive theory of multimedia learning. Adapted from Mayer, R. E., 1947. (2001). Multimedia Learning. Cambridge; New York: Cambridge University Press p. 37

According to Kuzu et al. (2007), Mayer is greatly concerned with reducing extraneous cognitive load. In attempting to reduce the extraneous cognitive load, various principles have been constructed and utilized to lessen the cognitive load; therefore, assisting the learners to obtain knowledge and improve their intellect. Mayer (2001) proposed seven principles for the design of multimedia instruction:

- Multimedia principles: This principle indicates that students learn best when words and pictures are used instead of only words.
- Spatial contiguity principle: This principle emphasizes that words and pictures should be rendered in close proximity.
- Temporal contiguity principle: This principle shows that effective learning occurs when matching pictures and words are presented together.
- Coherence principle: According to this principle, learning is enhanced when extraneous words, sounds and pictures are excluded from the media presentation.

- Modality principle: This principle rationalize that students acquire knowledge better when narration and animation is utilized than the use of on-screen text and animation alone.
- Redundancy principle: Here Mayer emphasizes that learning occurs with the combination of narration and animation than the utilization of narration, animation and on-screen text.
- Individual differences principles: Mayer rationalized that the design effects in multimedia learning are most favorable for low-knowledge learners and high-spatial learner than for the high-knowledge learners and low spatial learners (p. 223)

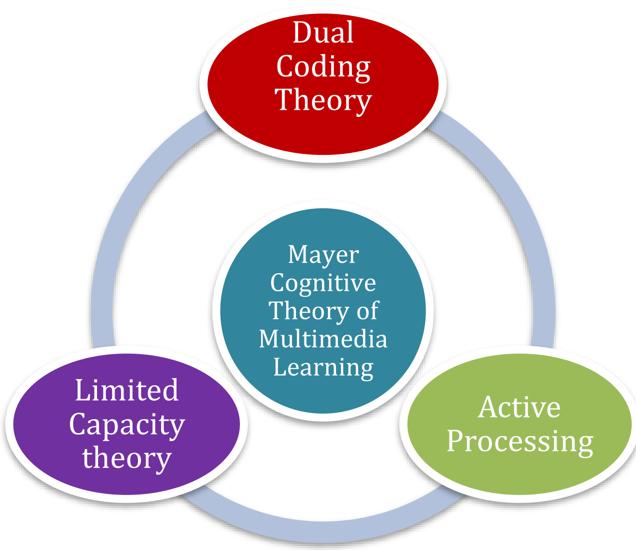


Figure 5. The theory that influenced Mayer's cognitive theory of multimedia.

This research study was framed by the concept that instructional practices should include multimedia designed instruction to maximize students' mathematic learning proficiency. Interview questions explored the teachers' and administrators' perspectives of the advantages and challenges of ST Math program as a multimedia human computer interaction program. Data analysis was grounded in the conceptual framework by using a priority codes which included the relevant elements of cognitive theory of multimedia learning.

The 21st Century Skills Theory

Another conceptual framework for this study is based on the 21st century skills theory. The primary focus of the Partnership for 21st Century Skills is to (a) enhance learners' knowledge; therefore, making them successful in schools and career life (Partnership for 21st Century Skills, 2006); (b) engage students in multimedia projects such as generating online game for the students (Senechal, 2010); (c) students' engagement with technology will enable them to acquire skills and knowledge needed to function successfully in the technological world of the 21st century (Redmond, 2015); (d) It is the responsibility of the schools and educators to make certain that students receive the education and training that will prepare them for the world workforce and the society at large (partnership for 21st century skills, n.d., Tucker, 2014); and (e) teachers can grasp students' interest when they can efficiently incorporate extensive kinds of media texts into their curriculum (Redmond, 2015).

The 21st century skills as shared by Jones (2014) include the following set of skills:

- Students mastering of the core subjects: English, English language arts, reading, mathematics, science, arts, geography, civic, government, history, and economics.

- Information, media, technology skills such as information, communication technology (ICT) literacy, media literacy, information literacy
- Learning innovation skills include innovation, creativity, critical thinking, problem solving, communication and collaboration.
- The 21st century themes such as global awareness, health literacy, environmental literacy, civic literacy, financial literacy, entrepreneurial skills, economic and business.
- Life and career skills which include social and cross-cultural skills, initiative, self-direction, flexibility, adaptability, leadership, responsibility, productivity, and accountability (p. 12).

This study's research questions are designed to explore how the integration of ST Math technology program as an element of the 21st century skills theory contributes to improving students' mathematics proficiency. The purpose of the study was structured by the fact that instructional practices should include elements of the 21st century skills especially technology application that must be relevant to students' learning (Partnership for 21st Century Skills, n.d., Tucker, 2014, Redmond, 2015). The interview questions explored the advantages of ST Math technology program and how as an element of 21st century skill contributes to improving students' mathematics proficiency through the lens of students' tests results. In the analysis of data, a priori codes based on the elements of the 21st century skills theory was used to develop the themes. Figure 5 illustrates the 21st century skills theory.

Figure 6. Partnership for 21st century skills model.

Literature Review Related to Key Variables and/or Concepts

Technological instructional programs have revolutionized teaching and learning (Colvin-Sterling, 2016; Luo, 2018; Luo & Murray 2018; Williams & Larwin, 2016). A growing number of schools around the country and beyond are occupied with transforming the learning atmosphere of the school and developing students' learning proficiency through technology tools and instructions (Onal & Demir, 2017). The three theories discussed above (activity theory, cognitive theory of multimedia learning, and the 21st century theory) have served as a course of action for the implementation of practical approaches to engaging teachers and students in a technology-driven instruction and learning. Students are motivated to come to school, remain in school and learn as a result of technology usage. Also, students are actively involved and are learning by doing, communicating, and receiving feedback. They also use their knowledge and skills to solve problems and engage in an active learning process (Colvin-Sterling, 2016; Kay, 2014; Luo, 2018; Luo & Murray 2018; Murray & Rabiner, 2014; Nart, 2016; Williams & Larwin, 2016).

Educational leaders understand that because the world is changing, the schools must change as well. The National Educational Technology Standards (2014) stressed the need to use learner-centered strategies and provide students with the appropriate digital tools and resources. They believed that a technology enriched classroom and instruction will produce students who will become problem solvers, decision-makers, and policy makers in the society. As the world is becoming more digital, so students are expected to engage with media and technology. Students' engagement with technology will enable them to acquire skills and knowledge needed to function successfully in the technological world of the 21st century (Redmond, 2015). According to Tucker (2014) the goal of the partnership for 21st century skills is to provide the educational system tools and resources needed to prepare the students to participate actively in the global economy. Most schools teach knowledge and skills stipulated by the core curriculum without making the connection to the 21st century workplaces, but they thrive to close such a gap (Tucker, 2014). Unless more effort is exercise in closing the gap between what students learn and its relevant to their living, the educational system of today will be insignificant

(Partnership for 21st Century Skills, n.d., Tucker, 2014). Different technological devices are used in the classrooms to support students' technology need. These devices include iPod, iPad, cell phones, tablets, projectors, document camera, Apple TV, and e-beam. Also, most recently, educators utilized different technology derived teaching and learning games to enhance classroom instructions.

Investigation of Some Technology Assisted Programs

The call for the enhancement and implementation of the 21st century skills has necessitated changes in the teaching and learning practices; therefore, educators have come up with different technology programs that are used to support and enhance classroom pedagogies (Falloon, 2017; Park & McLeod, 2018; Swallow, 2017). Both teachers and students' access to technology devices have doubled over the past years (Swallow, 2017). While some of these programs are very effective, some have come under criticism. Grant (2015) examined the use of mobile computing devices in K–12 classrooms utilizing a qualitative case study approach. Data were collected from nine K–12 teachers through the interview process. Findings revealed that mobile computing devices motivates and engages students in their learning. Similarly, Swallow (2017) exploit a qualitative multiple-case study to examine the influence of one-on-one technology initiative on the teaching practices at a catholic school. Participant for the study were 4 middle school teachers. Data were collected through interview, observation, historical documents and field evidence. Findings revealed that technology promotes the desired teaching and learning outcome. Also, Bowens and Warren (2016) employed a mixed methods research to investigate the impact of the Jaime Escalante Math Program

(JEMP) on the students' mathematics achievement in an urban school using 2 years of student math assessment data. The findings showed significant growth in participants' mathematics scores, therefore revealing that the program was useful. Likewise, Carrick, Miller, Hagedorn, Smith-Konter, and Velasco (2016) evaluated the influence of the Pathways to the GeoSciences Summer High School Program on students' admission and retention in the geosciences path. The objective of the evaluation was to assess the effectiveness of the program in meeting its goals. A total of 245 students mainly Hispanic American origin in El Paso, Texas participated in the program over a period of 10 years. Data were collected using three types of survey instruments: pre- and post-participation surveys, formative evaluation of daily activities, and annual post-participation surveys. The short-term results indicated positive changes in student attitudes toward science and the geosciences while long-term showed that 55% of the participants remained in the geosciences path and 20% either majored in or were enrolled in geosciences major. Equally, Geer (2014) investigated the impact of the Success Maker Software program on the state mathematics tests of 4th-grade students. He discovered that integration of technology in the 4th-grade curriculum was beneficial and had a substantial effect on the 4th-grade students' state mathematics tests.

In the same way, Williams and Larwin (2016) investigated the implementation of one on one computing environment and its effect on student achievement in Ohio high school. The result shows that one-on-one computing programs have the potential to improve student achievement. All the above studies show that the applications of technology instructional programs are capable of enhancing classroom instruction and enable students to master or become proficient in the subject.

Not only are technology programs applied in the classrooms, but some of these programs are in form of simulations, games and virtual world's applications that promote teaching and learning. Merchant, Goetz, Cifuentes, Keeney-Kennicutt and Davis (2014) conducted meta-analysis research to examine the effect of some technology used in the K-12 classrooms. The result shows that simulations, games, and virtual worlds were effective in improving the learning outcome gains. Similarly, Decoito and Richardson (2016) examined the potentials of a digital game. Participants agreed that science digital online games promote engagement, reinforcement of content material, advance 21st-century skills, and that computer-based games have significant educational value and can assist students to learn the principles, theories, and problem-solving in science. Also, Wu (2018) stated that literature supports the notion that well-designed digital games can facilitate and promote learning since the designs are based on some learning principles. These principles include providing immediate feedback, sandbox, customization, and adjustable difficulty level to motivate and meet the needs of the players (Wu, 2018). Lately, Edwards and Boody (2017) maintained that computer games tend to enhance students learning and actively involve students in a multisensory instruction atmosphere; therefore, improving mastering of the subject taught.

Although technology-assisted learning is beneficial to all students, for some students (At-Risk students/disability students/ inattentive students), this may be the best method of learning because it assists in providing visual representations, interaction, and enabled differentiated and individualized instruction (Murray & Rabiner, 2014; Park & McLeod, 2018; Zheng, Warschauer, Hwang, & Collins, 2014). According to Zheng et al. (2014), at-risk students benefits from any technology-facilitate science instruction. It increases their science achievement, knowledge, and comprehension. Also, it encourages and inspires students to choose a STEM-related career. Besides, research indicated that when at-risk students are involved in scientific methods hands-on inquiry-based mediations of constructing and investigating, it enhances their understanding of science concepts and achievements (Zheng et al., 2014). Murray and Rabiner (2014) emphasized that Computer-Assisted Technology Instruction (CAI) is a vital mediation remedy for inattentive young students who have certain disabilities. It can enhance the quantity of instructional time required of them especially in early elementary school. According to Murray and Rabiner (2014), data maintained that CAI would help older students with inattentive behavior become less disruptive and offtask in class during instruction.

Technology has become an integral part of teaching and learning. Various researches point to the fact that using technology for instructional purposes has revolutionized the methods of classroom teaching and learning. With an effective application of technology in the classroom, the teachers' role shifts from that of an instructor to a mediator or facilitator who guides whenever necessary. Using technology, students are motivated to learn, participate in inquiry-learning, project-based learning, and improve in their problem-solving and communication skills. Also, students now can learn through images, sounds, and text. It is, therefore, imperative for teachers to apply technology in the classrooms to support their classroom practice putting into consideration the importance of technology reviewed in the above pages.

The Use of Technology in Mathematics

According to Bhagat and Chang (2015), mathematics is one of the major subjects in the curriculum of any school and grade levels and one of the criteria for admission into any technological and scientifically driven profession. It is, therefore, imperative for students to master and be successful in mathematics. Although understanding mathematics is crucial, many students are not meeting expectations in this area. Callan and Cleary (2018) affirmed that students' lack of proficiency in mathematics is a nationwide concern and it has prevented many students from completing higher degree and pursuing mathematics related profession. A considerable number of students find mathematics difficult, boring and suffer from fear and failure of the subject (Levi et al, 2016; Onal, & Demir, 2017; Yenmez, 2017). Educators acknowledged the necessity for implementing different approaches, strategies, curriculum, and teachers' professional development that is essential to the improvement of students' mathematics proficiency (Balenlyne & Varga, 2016; Murphy, 2016). Eronen and Karma (2018) pointed out that learning has gradually shifted from the behaviorist point of view to the constructivist prototype that put emphasis on cognitive practices. The various methods that educators utilized in the classroom to foster teaching and learning can influence students' level of understanding of the subject (Balenlyne & Varga, 2016; Falloon, 2017; Levi et al., 2016; Murphy, 2016; Park & McLeod, 2018; Herro & Quigley, 2016). Educators nationwide call attention to the necessity for effectual mathematics instruction that will benefit all students including students with disabilities (Mulcahy, 2014; Yenmez, 2017). There is the need for educators to study areas of improvement of mathematics and apply higher-order thinking in learning the subject so that students will be motivated and inspired to not only learning the basics of mathematics, but also see the practical uses of mathematics in the real-world (Karatas, Tunc, Yilmaz, & Karaci, 2017; Murphy, 2016; Yenmez, 2017).

There is a vital move to establish powerful technology-rich teaching and learning environment for education in the twenty-first century. Technology provides new methods. Strategies, and tools for educational activities (Karatas et al., 2017; Leonard et al., 2016). Technology usage in the mathematics class can bring a lasting solution to students' boredom and anxiety in the mathematics class (Balenlyne & Varga, 2016; Falloon, 2017; Herges, 2017; Musu-Gillette, 2015; Onal, & Demir, 2017; Yenmez, 2017). It provides significant independence that enables learners to establish how, when, and where to learn; therefore, offering additional academic answers for inspiring and shifting from the traditional approach of teaching (Eronen & Karma, 2018). The influence of technology in the teaching and learning of mathematics is continuously developing. It is important to note that technology not only help the students to learn mathematics concepts proficiently, but it can enhance a deeper understanding of mathematical concepts; therefore, bringing about a significant increase in learning achievement and proficiency (Budinski & Milinkovic, 2017; Levi et al., 2016).

According to Smith (2018) with the aid of technology, students take ownership of their own learning, participate in activities that stimulate deeper thinking and the role of the teacher become that of the facilitator. Student-centered approaches offer students opportunity to collaborate and cooperate as well as to self-guide in making decisions regarding their own processes (Eronen & Karma, 2018; Levi et al., 2016). Eronen and Karma, (2018), stated that many students reported that the feeling of self-guidance improves learners' meta-cognitive skills and ability to evaluate their own work. Eronen and Karma (2018) cited example involving the combination of geometric and symbolic thinking. They believed that technology for instance computer algebra system (CAS) calculators offer an appropriate setting wherein the latest mathematical conception in the problem-solving process can be learned through the manipulation of geometric or symbolic representations of the concept. Gresalfi & Barnes (2015) emphasized that technology designed instructional games gives immediate feedback regarding the quality and level of students' performance. These feedbacks are sorely formative and occur during the game; therefore, offering information that allow the players to change their behavior or activity.

One technology program that has been created to close the gap of students' lack of proficiency in mathematics is the ST Math technology program. The Mind Research Institute created ST Math for K-12 education.

Spatial-Temporal Math Technology Program

In contrast to the traditional method of teaching mathematics, ST Math uses game-like visual to illustrate and teach math skills. Students help JiJi, a penguin, overcome obstacles by solving math puzzles. Each time a student solves a puzzle correctly, Jiji walks across to the next task. The level of difficulties increases as the student progresses into the next phase. Students have the opportunity to work independently at their pace on mathematics standards at home or anywhere technology is available using a desktop computer, laptops, and iPads. Students log into ST Math with their password to work on mathematics standard at any given time at their learning ability pace. Díaz, Nussbaum, Ñopo, Maldonado-Carreño and Corredor (2015) emphasized that good teaching put into consideration specific student needs, diversity within the classroom and individual student's progress within the learning process reflecting the different paces of learning. Similarly, Levi et al, (2016) highlighted the need for a student-centered model of learning culture instead of teacher-centered model. Özerem and Akkoyunlu (2015) stressed that educators should design learning process or methods that put individual students' learning styles into consideration instead of continuous constant learning approaches. Multimedia learning environments teaches by giving importance to individual differences. The cognitive theory of multimedia learning of Mayer (Mayer 2001, Mayer et al. 2004) focuses on the concept that students best acquire knowledge when words and pictures are presented concurrently rather than with words alone and students have the opportunity to make connections between the verbal and graphic conceptual schema construct they have created (Mayer's 2001, Kuzu et al., 2007). ST Math seeks to teach mathematics using visual and putting individual needs into considerations.

ST Math technology program was developed from neuroscience research at the University of California, Irvine. Mind Research Institute's unique methodology examined the brain's inborn spatial-temporal thinking capability. According to Mind Research institute, the spatial temporal remains the foundation of revolutionary intelligent and high-level problem-solving skills. The problem-solving skills in technology-rich environment are the ability to use digital technology to perform practical tasks. The high-level problem-solving skills can be developed with educational activities (Working, 2018; Yagci, 2016). The spatial-temporal reasoning, lets the brain sustains visual and mental illustrations in the short-term memory (Mayers, 2001, 2015); therefore, allowing multiple thinking steps ahead such as knowledge, comprehension, application, analyses, synthesis and action taking respectively (Suardana, Redhana, Sudiatmika & Selamat, 2018). The ST Math software games that resulted from this research consist of language-free and animated demonstration of math concepts. At first, students come across visual puzzles that are free of symbols. When they mastered the visual representation, symbols are progressively incorporated into the puzzles (Nisbet Luther, 2014). Kribbs and Rogowsky (2016) pointed out that visual-spatial representations are part of the mathematics problems-solving process as it promotes the students' problem-solving skills. The basic parts of the visual-spatial representations are pictorial and schematic representations. Pictorial representations show the objects or persons in a word problem while the schematic representations ascertain the spatial connection between the problems (Kribbs & Rogowsky, 2016). The principles of schematic visual- spatial representations can provide the required structure, teaching and assistance in the mathematics classroom (Kribbs & Rogowsky, 2016).

Effectiveness and Advantages of ST Math in Teaching Mathematics

Rutherford et al., (2014) examined the ability of ST Math to produce gain in elementary school students test scores after a 1-year implementation. In addition, they investigated if ST Math is more beneficial for ELL students and students who participated in ST Math at different proficiency levels. Participants were elementary school students drawn from 52 schools that are recognized for performing below average on the state test. The total data collected was from 13,803 students who took the Mathematics and English Language Arts test for schools (Rutherford et al., 2014, p. 366). These students were divided into two cohorts. Results indicated that 1-year of ST Math integration in the math curriculum produced low gains in the test scores of the students. Although the outcome for 2 years was greater than that of 1-year, the gains were not statistically significant.

Similarly, Schenke et al., (2014) examined the results of a randomized control trial of standards-based mathematics software - Spatial-Temporal Mathematics (ST Math) on elementary school students third–fifth grades within 52 southern California public elementary schools. The authors described the outcome of the ST Math program on students' number sense skills and revealed the fundamental of the game design that has contributed to students' achievement. The result shows that there is a significant impact of the ST Math program on the elementary school students' basic number sense skills which was evaluated by a standardized measure of mathematics achievement (p. 215).

Wendt et al., (2014) stated that there were significant differences in the standardized mathematics scale scores of students who participated in ST Math program from those who did not participate. The authors evaluated spatial-temporal math programs in California for 2–5 grades. Data were collected from 212 schools with 463 second–fifth grades classes. These classes implemented the ST Math program. Using a matched-comparison, quasi-experimental design, the authors compared students in grades that implemented the ST Math program to students in grades that did not implement ST Math program. The findings revealed that the average standardized Mathematics scale scores of those who participated were higher than those in grades that did not participate.

Nisbet and Luther (2014) emphasized that ST Math has benefited many students in increasing the standardized test scores and mathematics proficiency. Students develop incredible persistence in problem solving as they move from one level of difficulty to the next level. Since the program is designed as a game to keep students engaged and trying to solve the mathematics puzzle themselves without any help, students are more attentive to the feedback that is given to them. They pointed out that ST Math presents a blended learning approach by reinforcing the core curriculum and establishing a classroom climate where students learn through a combination of learning approaches. Blended learning involves more than one approach to learning. According to Bellard (2017) and Nisbet and Luther (2014) blended learning utilizes digital curricula, the social interaction of the classroom environment and the components of the behavioral, cognitive, and constructive learning theories. ST Math provides students with visual approach to learning mathematics using technology tools and the opportunity to discover mathematics concepts for themselves. The use of visual is combined with core mathematics instruction using class rotation strategies (Nisbet & Luther, 2014).

In this research, the advantages and challenges of ST Math in middle school, seventh and eighth grade was explored. All the above research was conducted in elementary school in 2014. There are no recent articles or records of any research conducted in the middle school and in my research site. Also, the study seeks to address the implementation of ST Math beyond 1-year period. The previous studies focused on the application of ST Math for a 1-year period (Rutherford et al., 2014; Schenke et al., 2014; Wendt et al., 2014). The question that originated out of these studies is whether continuous implementation of ST Math beyond a single school year will have a more beneficial effect on the general students' mathematics proficiency or individual students over time due to multiple years of exposure or long-term effects after the exposure ends (Rutherford et al., 2014; Schenke et al., 2014; Wendt et al., 2014).

Middle School Age Group

Typically, students in Grade 6 through 8 with an average age of 11 to 14 are classified as middle-school students. Middle-school age is regarded as one of the most challenging stages of life. Students start experiencing some academic challenges of change of classes, high teacher expectations, and more difficult work (Balenlyne & Varga, 2016; Romero, Master, Paunesku, Dweck, & Gross, 2014). They are given some freedom and independence as they move to different classrooms for different subjects. They no longer have a teacher, but multiple teachers. Students begin to undergo puberty and the developmental needs associated with the adolescent's years. According to Yeager (2018), adolescence age is a period of learning when students learn to take responsibility for their learning and cope with school and social life demand and at the same time deal with the increasing positive or negative emotions associated with their age. At this age, adolescence feel empowered and think there is no need for adult guidance. They expect more independence and autonomy in handling personal choices. Yeager (2018) stated that Bradford Brown, a developmental psychologist at the University of Wisconsin in a report for the National Academy of Science wrote that students in their adolescence age have four developmental preoccupations. These preoccupations involve they concern of making commitments to particular goals, activities and beliefs, standing out, fitting in with peers and measuring up to expectations. The desire to fit in with peers becomes paramount leading to a decline in grades and an increase in negative attitudes toward school (Romero et al., 2014).

All these middle-school students' characteristics coupled with lack of proficiency in basic mathematics from elementary school contributes to students' performing below average on state standardized testing (Balenlyne & Varga, 2016; Nelson et al., 2016; Romero et al., 2014; Yeager, 2018). This failure to master the necessary skills in lower grades will affect the mastering of more advanced skills in higher grades (Cirino et al., 2016; Flores et al., 2015; Nelson et al., 2016). According to Hill, Witherspoon and Bartz (2018), adolescents can take responsibility and becoming active participants in their education. Their ability to reason theoretically, learn from experiences and concerns for multiple perspectives increase. It is equally a period of immense learning discovery, adventure, exploration, and opportunity (Yeager, 2018). Çetinkaya, Özgören, Orakcı, & Özdemir (2018) stressed that middle-school years are when students' perceptions toward math start to form. It is therefore imperative to provide them with Research-based mathematics curriculum that will enable them to develop a positive attitude toward math.

Mathematics Curriculum

Mathematics learning can be a challenge for some students. However, the methods of instruction used by the educators can contribute to the level of understanding and mastery of the students (Marita & Hord, 2017). As students enter the middle-school grades, mathematics standards become more complex and necessitate higher order thinking skills. Marita and Hord (2017) stressed that “mathematics educators emphasized that procedural fluency, conceptual understanding, problem-solving competence, and reasoning are necessary for students to be proficient in mathematics” (p. 30). For most 21st century jobs, advanced levels of mathematical and technical skills are needed; therefore, students must possess adequate mathematics skills to solve problems in challenging circumstances (Marita & Hord, 2017; McDuffie et al., 2017). The above view is also accepted by mathematics education researchers, practitioners, and policy makers (Marita & Hord, 2017; McDuffie et al., 2017). It is the responsibilities of teachers to work with and enact curriculum suitable for the classrooms to achieve the desired outcomes.

Several curriculum standards are implemented, but since 2010, the Common Core State Standards for Mathematics (CCSSM) were acknowledged and adopted by majority of the states in the United States (Davis, Choppin, Drake, Roth McDuffie & Carson, 2018). The mainstream of students in the United States is taught using the CCSSM curriculum; therefore, making CCSSM the focus of attention for many stakeholders (Teuscher, Tran & Reys, 2015). The common core standards are integrated into the curriculum of the schools and the state assessments (Davis et al., 2018). The goals of

CCSSM include conceptual understanding of many foundational co-coordinating problem-solving steps and the ability to use retrieval-based skills to solve computations and word problems. These skills enable students to be successful problem solver, an essential component for overall mathematics achievement (Teuscher et al., 2015). The mathematics common core standards for middle school include number system, functions, expressions and equations, ratios and proportions, geometry, statistics, and probability (Mulcahy, Maccini, Wright & Miller, 2014, p. 147).

Every student succeeds (ESS, 2015) supports rigorous accountability and growth regarding college and career readiness for all students, thereby putting pressure on educators to assist students to be successful in challenging mathematics, developing higher levels of thinking and problem-solving skills (ESS, 2015). According to the National Center for Education Statistics (2005), 60% of fourth graders and 67% of eighth graders perform below proficiency in mathematics (Codding, Mercer, Connell, Fiorello & Kleinert, 2016). Students' failure is attributed to the fact that they are not proficient nor mastered the necessary mathematics skills by eighth grade therefore are unprepared for algebra coursework. The three vital foundations for "algebra are (a) fluency with whole numbers (b) fluency with fractions and (c) fluency with essential components of geometry such as finding the perimeter, area, or volume of shapes using formulas" (Codding et al., 2016, p. 20). The common core standards aim to increase the level of difficulty, congruity, and key on the mathematics learning objectives (Codding et al., 2016).

Relevance of Mathematics in Middle School

Teaching mathematics in school has become a necessity. The society has a certain level of knowledge about the need for mathematics education. Mathematics is classified as one of the most significant courses for students at every step of their education life (Çetinkaya et al., 2018; Musu-Gillette et al., 2015; Nelson et al., 2016; Park & McLeod, 2018). According to Çetinkaya et al. (2018) mathematics is both a scientific and theoretical branch of learning that enables people to think logically and assists in understanding life and generating ideas. It also helps students with essential skills "such as comprehending, thinking, making connections between events, reasoning, making predictions, and problem-solving" (Çetinkaya et al., 2018, p. 32). In addition, mathematics knowledge and skills will prepare students for high school, college, and any chosen career. Without competence in mathematics, an individual will struggle to maintain a lucrative job and handle personal funds (Stuttz, 2017). Similarly, Brackett (2016), Felton (2014), Onybuchi and Norman (2014), and Sparapani et al. (2015) provided information on the importance of mathematics as one of the core subjects that are nationally and internationally recognized. Likewise, Felton (2014) listed three importance of math as (a) enabling students to learn to value diversity (b) recognize mathematics in their lives and environment (c) scrutinize and critically assess social issues and injustices. Aguirre (2016) and McNeil and Fairley (2016) provided a detailed analysis of the role and connection between mathematics education and social justice, pointing out that young students using mathematics can understand and change their lives and the world they live in.

Understanding mathematics is important, yet many students are not meeting expectations in this area. Callan and Cleary (2018) stated that mathematics underachievement is a national concern and students struggle in mathematics subject has hindered many from pursuing and completing related higher degrees or career. Similarly, Herges, Duffied, Martin and Wageman, (2017) affirmed that underachievement of K-12 students in mathematics is an ongoing issue in schools across the United States. A considerable number of students find mathematics difficult, boring and suffer from fear and failure of the subject (Onal & Demir, 2017). Nelson et al. (2016) attributed students' failure to lack of mastering of the underlying computation skills in elementary school. Inability to master the necessary skills in lower grades will affect the mastering of more advanced skills in higher grades (Cirino et al., 2016; Flores et al., 2015; Nelson et al., 2016). Equally, Musu-Gillette et al. (2015) and Felton (2014) stated that students' belief in their mathematics ability, interest, and sense of the importance of math relates to how significantly they take the subject in high school. It also foretells their desire to undertake a math career or class in college. It is therefore paramount that middle-school students, seventh and eighth grade master mathematics skills. Mathematics skill learning is hierarchical. It builds from one to another. Failure to master the necessary skills in lower grades will affect the mastering of more advanced skills in higher grades (Cirino, Tolar, Fuchs, & Huston-Warren, 2016; Flores, Koontz, Inan, & Alagic, 2015; Nelson et al., 2016).

School Accountability, Standardized Testing, and Mathematics Assessment Practices

School accountability, standardized testing, and mathematics assessment practices have been a long-standing tradition in the United States (Bae, 2018, Balenlyne & Varga, 2016). An important part of accountability is the attendance accountability. The federal and state funds are allocated based on students' enrollment in schools and the classification of the student population (Snyder, 2016). Some schools are classified as Title 1 schools. Title 1 is an elementary and secondary education Act of 1965 (ESEA) that provides extra instructional services for schools with high poverty rates (Snyder, 2016). It is a requirement that each state test students and make certain that the expected percentage of students in the diverse students' categories are performing adequately or improving. Since the 1990s, school accountability, in particular test-based accountability, has been part of the K–12 educational policy (Bae, 2018, Balenlyne & Varga, 2016). Accountability intends to put an emphasis on the state standards and ensure that teachers implement these standards (Polikoff, Greene, & Huffman, 2017; Stotsky, 2016). Data from these tests are used for school accountability and assist educators in improving the rigor of the classroom teaching and learning. It also provides essential data to support education research and improvement. The school accountability procedure under the No Child Left Behind (NCLB) labels schools that have failed to meet the improvement requirement as "in need of improvement" or "failing school," and in some instances, the school is restructured (Polikoff et al., 2017; Stotsky, 2016).

Each state is permitted to choose and administer preferred standardized tests that align with the state curriculum and standards. There are two types of Standardized tests, criterion-referenced and norm-referenced. Criterion-referenced tests assess students' understanding or competence in a particular subject. On the other hand, norm-referenced tests are used to classify or place students; it does not measure competency (Polikoff et al., 2017; Stotsky, 2016).

In addition to the standardized testing, schools are expected to use summative and formative assessment (Broadbent, Panadero, & Boud, 2018). Summative and formative assessments are a critical component of mathematics instruction. They are used to examine student's knowledge, awareness, and abilities regarding the content they have learned (Baird, Andrich, Hopfenbeck, & Stobart, 2017). Assessment designs should reflect and impact the outcomes of learning, hence information generated from the theories of learning and assessment should benefit and complement each other. In other words, there should be a correspondence and better alignment between learning and assessment theories (Baird et al., 2017; James, 2017).

According to James (2017) test developers should focus on questions such as "what is learning and how should it take place? Is learning about content or processes or outcomes? Is it a property of an individual or is it essentially social? Is learning equivalent to memorization made manifest through consistent performance? Does it involve the application of knowledge (declarative and procedural) to solve novel problems? Is new knowledge-generation a form of learning? Is it about appropriate and creative use of resources toward a possible range of valued outcomes, retrospectively evaluated rather than pre-specified? Is it purely cognitive or does it have haptic, affective, and conative dimensions involving the development of practice, values and the will to act (motivation and effort)? Or is it all these things, with varied emphases according to context?" (p. 406)

James, (2017) offered the subsequent suggestions to what may comprise sociocultural assessment practices:

- Assessment should not be separated from the local setting just as learning cannot be separated from the big ideal it incorporates.
- Assessment should be conducted by the community in which the learning is situated instead of by an external evaluator.
- Group learning should be assessed just as individual learning. Both are equally important.
- Assessment should involve in vivo studies of complex problem solving. In other words, assessment should be a process of examining group of students in their local settings.
- The most important factor is on how properly people apply competence in the utilization of the tools and resources at their disposal to originate or create problems, work efficiently and assess their efforts.
- Learning outcomes should be a collection of different types of reports. For examples, narrative accounts, audio media and visual media.
- Evaluation should not be quantified as is always the case, but comprehensive and qualitative in nature. (p. 408)

In addition, Broadbent et al., (2018) stressed that assessments enable the teachers to frequently measure students understanding of the concepts that have been taught and determine future instruction. Along with the summative assessments, informal assessments should also be administered every class period to check the students' progress. ST Math technology program comprises both summative and formative assessment. Students take a pretest at the beginning of the program and a summative (posttest) assessment at the end of the program. Also, in between each of the mathematics curriculum standards, students take a pretest and posttest for each of the standards. Students who made a 100% on the pretest have the privilege of skipping that standard and moving on to the next standard. Students' mathematics standardized test results, along with the summative and formative assessments are used to measure the overall success and usefulness of the ST Math program.

Teachers Perceptions on the Use of Technology in the Classroom

In this research, I investigated teachers and administrators' perspectives. Teachers' beliefs influence their classroom behavior and acceptance of technology programs (Chan, 2015). According to Firmender, Gavin and McCoach (2014), how well an education program is implemented depends on teachers' perceptions about the program. Firmender et al., (2014) stated that strategies and instructional practices that teachers use in the classroom influence student learning. The task of teaching with a program may be difficult for teachers if they are not familiar with the program. Teachers influence students' achievements and proficiencies in the different subjects when they impact their knowledge to students (Akpan & Saunders, 2017; Fulmer & Turner, 2014).

According to Yenmez (2017) it is the responsibility of the teacher to assist students in the learning process by identifying and eliminating students learning difficulties. Kiru (2018) stressed that teachers, administrators, and policymakers should understand how technology are utilized and the frequency of usage in teaching and learning to develop an understanding of the relationship between teachers' technology use, teacher beliefs and teachers training instead of making assumptions that the mere presence of technology in the classroom leads to effective technology usage in teaching and learning. Karatas, et al. (2017) accentuated that educationist should examine teachers' beliefs and perceptions to gain an understanding of the characteristics of teachers so that they can train teachers and also prepare courses for effective integration of technology. The most significant factor in incorporating technology and successfully implementation of technology in the classroom is teachers' attitude regarding the integration of technology in teaching and learning (Murphy, 2016). This information can inform instructional practices and promote effective technology use that enhances instead of hinders student learning.

Limitations of Using Technology in the Classrooms

The call for the implementation of the 21st century skills to be taught in all U.S. schools is halted by some concerns, which if not properly dealt with will continue to impede the success of its implementation. According to Budinski and Milinkovic (2017); Brown (2018) and Quigley and Hero (2016) many problems are associated with technology integration in the classroom. These include and not limited to insufficient computer devices, funding, proper integration of technology into the curriculum and the teachers inadequately trained to apply technology into the classroom instruction. Kiru

(2018) also reaffirmed that research reveals disparity in technology availability, access, frequency of technology usage and the significance of the application of technology during classroom instruction. Similarly, Chan (2015) added that the use and adoption of technology in mathematics is not widespread in many educational systems due to teachers' knowledge and attitude toward technology, access to technology, supports given to the teachers and the school settings. Another important limitation accentuated by Grant (2015) is the challenge of unstable, unreliable network and technical issues. It is imperative to consider the existing school patterns toward the use of technology, as well as teachers' assumptions, perspectives, and attitudes toward using technology. These aspects contribute to the value of technology application in any school (Kiru, 2018).

Summary

The three theories discussed provided the theoretical foundation for understanding human – computer interaction. Also, I reviewed how technology has revolutionized teaching and learning in the 21st century. The importance of technology as a classroom tool cannot be overemphasized. It has contributed immensely to changing students learning and teaching instructions in all subjects including mathematics. According to the National Center for Education Statistics (2015), only 40% of fourth-grade students and 33% of eighth-grade students in the United States performed at or above the proficient level on the National Assessment of Educational Progress mathematics assessment. To address the student achievement gap and to support students' mastery of the necessary mathematics skills in middle-schools, ST Math has been proposed in middle-school, but its advantages and challenges on students' learning and proficiency curriculum is yet to be determined.

Chapter 3 focuses on the research design and rationale for the design. It also includes the role of the researcher and the methodology applied. Equally, I discussed issues of trustworthiness, and the ethical procedures related to the data collection process.

Chapter 3: Research Method

ST Math has been recommended as a means of improving students' mathematics proficiency, but the program's advantages and challenges in middle school, specifically seventh and eighth grade, have not been examined. Mathematics underachievement has been a major concern nationally (Brown, 2018; Callan & Cleary, 2018; Levi et al., 2016); therefore, stakeholders—parents, administrators, teachers, and the school community—seek ways to improve students' mathematics proficiency. National Educational Technology Standards (2014) stressed the need to use learner-centered strategies and provide students with appropriate digital tools and resources. ST Math has been classified as one of those tools. Midland Middle School has been implementing the ST Math program in Grades 7 and 8 for the past 4 years.

The purpose of this qualitative single case study was to examine the advantages and challenges of implementing ST Math on students' learning and proficiency in mathematics in seventh and eighth grade. To accomplish this, I examined teachers' and administrators' perspectives of the program as a research-based curriculum that seeks to assist students in mathematics proficiency. I also descriptively examined test results about the overall changes in student test scores when continuous implementation of the program is used in seventh and eighth grade compared to prior to its use.

In this chapter, I discuss the research questions, the research design and rationale for the design. I emphasize the role of the researcher, and the methodology utilized. Also, I highlight the issues of trustworthiness, and ethical procedures.

Research Design and Rationale

In this case study, I examined the advantages, and challenges of implementing the ST Math program on students' learning and proficiency in mathematics in middle-school, seventh and eighth grade. The study addressed the following research questions:

RQ1: What are teachers' and administrators' perspectives of the advantages and challenges of implementing the ST Math multimedia technology game-based instructional program on students' learning and proficiency in mathematics in seventh and eighth grade?

RQ2: What do students' test results indicate about the overall changes in test scores with the continuous implementation of the ST Math multimedia technology instructional program in seventh and eighth grade?

In this research, I employed a qualitative single case study to answer the above questions. The research design is a fundamental component of any research. It is the strategy that begins with general assumptions and leads to the specific process of data collection and data analysis (Creswell, 2009, 2014). According to Arseven (2018), research design is a plan that leads the researcher from the beginning to the end of research. A research design helps the researcher answer the question of what the problem is, who to study, types and methods of data collection, methods of data analyses, the timing of the research, and solutions to the research questions. Qualitative research is mainly investigative research that searches for in-depth understanding of a social phenomenon within participants' natural setting (Creswell, 2009, 2013, 2014; Ngozwana, 2018). A qualitative researcher gathers non numerical data. While engaging in the research process, the researcher must be objective to ensure trustworthiness (Creswell, 2009; Frankfort-Nachmias & Nachmias, 2008; Ngozwana, 2018). A qualitative study provides insight into the reasons, opinions, and motivation of the phenomenon to help the researcher develop theory and interventions. The method and hypotheses formulated from qualitative research can be followed with quantitative study (Arseven, 2018; Crewell, 2009). I considered using the quantitative research method, but it was not suitable for this research because such research focuses on investigating observable facts using statistical or mathematical methods. As discussed above, my research was intended to study a phenomenon—ST Math—in a particular setting—Midland Middle School—to discover the usefulness of the program and develop interventions if appropriate.

There are various designs of qualitative research, such as case study, grounded theory, and phenomenological. The current study is a case study design. Arseven (2018) described a qualitative case study as a research approach that centers on the examination of a problem of an individual, group, or organization and that uses *how* and *why* questions. Case study gives researchers tools to study phenomena within their contexts. A case study requires participant observation, detailed interviews, and thorough evaluation of collected documents (Arseven, 2018; Creswell, 2013; Ngozwana, 2018). The phenomenon under study in this research was the ST Math program implemented in a middle school in the southern region of the United States. Other qualitative research designs were not suitable for this research. Phenomenological research involves participant experiences in a particular event. Ethnographic research is used to describe and study cultural features of a specific group. Grounded theory research generates and explains a theory. The historical method is used to describe past events and make connections with future choices. Lastly, the narrative method documents occurrences of a particular event over a prolonged period (Creswell, 2013; Creswell & Creswell, 2017). None of these designs were appropriate for the focus in this study.

Role of the Researcher

In any research, it is essential to outline the role of the researcher. In this research, I played the role of an objective researcher, interviewer, and data collector. As the interviewer, I conducted one-on-one interviews with the participants: three mathematics teachers, an administrator, and the SIP leadership team facilitator. I also recorded and transcribed the interviews and collected archival data from the school and analyzed them.

As a teacher at the school site, my teaching assignment is to facilitate the computer lab where students participate in the ST Math program. The three mathematics teachers and the SIP leadership team facilitator are my colleagues and the administrator is my employer. The participants were not my subordinates nor do I play any supervisory role over them. Also, I was not pressured to concede in any way by the administrator.

Although I have a cordial working relationship with the participants, I strictly maintained a research relationship with them throughout the research period and did not let the work relationship interfere with the data collection process. I do not have any bias against the program nor the participants. I asked the participants’ permission by sending a consent letter to participate in the research. I did not bribe the participants financially or otherwise, nor did I use coercion for the study. The participants were made aware of the intention of the research and their role in examining the ST Math program used to promote student mathematics proficiency and the importance of improving student achievement in mathematics.

Because the study was conducted in my work environment, the first step was to contact the school district and the principal of the school to ask for permission to carry out the research. When granted the permission, I proceeded to send the consent letter to the participants explaining the research and their role in completing the research. Upon their agreement to take part in the interview, we set a date for the interview. Each of the participants was given the opportunity to select the best convenient time for the interview. I made it clear to participants that the interview was voluntary. No incentives were provided or coercion involved, but at the end of the data collection process, I provided participants with a $20 thank you gift card for their time and input. Participants were made to understand the benefits of the data collection and were urged to be as honest as possible. There was no harm involved in this research. I ensured that the interview questions were devoid of words or language that would be upsetting, emotionally harmful, or reputationally damaging.

Methodology

Participant Selection Logic

In a qualitative study, the selection of participants is a vital aspect of the study. The type of participant group researchers use depends on the research problem they are investigating (Frankfort-Nachmias & Nachmias, 2008). In this study, I chose a school district in the southern United States as the location of the study. Midland Middle School is a Title 1 school; 63.96% of its students come from economically disadvantaged homes.

The school population consists of 230 seventh- and eighth-grade students. Demographics data revealed that the student body is 98.65% Black with 0.45% White and 0.45% two or more races. More than half of the student population, 55.41%, is female and 44.59% are male students. The school has 13 teachers, 1 reading coach, 1 counselor, 1 media specialist, 2 instructional support staff, and a principal. Included in the teachers are the 3 mathematics teachers for Grade 7 and Grade 8.

I chose this setting because state standardized test indicated that students are below average in math proficiency. In 2013–2014, less than 10% of the students scored on the math proficiency level. To acquire levels of proficiency, administrators needed research-based teaching strategies that will improve students' mathematics proficiency. ST Math program was purchased and implemented in the school for all students. The advantages and challenges of ST Math program in this School has not been examined since the inception of the program in 2014. It is proper to explore the efficacy of the program.

Sampling

In research, sampling is the process of identifying the place, selecting a specific group, type of individuals, event, or process from a specified population of interest to study, investigate or experiment (Creswell, 2014; Ngozwana, 2018). Qualitative case study collects data on specific cases, events, or actions from these groups to clarify or deepen the researchers understanding or enhances previous research about the phenomenon being studied. Qualitative case study employs purposeful sampling or criterion-based sampling. Purposeful sampling allows you to search for individuals or cases that provide insight into the specific situation under investigation. These selected individuals or cases bring value to the study. Researchers can discover more about the issues under examination from them, but not because the participants are easily accessible (Ishak & Bakar, 2014; Burkholder, Cox, & Crawford, 2016).

In this study, I used purposeful sampling. Purposeful sampling allows you to search for individuals or cases that provide insight into the specific situation under study. These selected individuals or cases bring value to the study. They provide insight and assist the researcher in understanding the research problem and providing answers to the research questions. The selected participants were in position to add value to the research due to their status, title and role played in the school. My sample setting is Midland Middle School described above. The phenomenon under study is the ST Math program. The participants for the study consisted of the three mathematics teachers, the school administrator, and the SIP leadership team facilitator. These participants have different roles at the chosen setting. Having different participants will allow for various voices, thoughts, and perception; therefore, promoting the triangulation of data. Other data that were collected were the students' ST Math pre/posttest scores and recorded standardized test scores from the last 3 years. The result of the study is used to determine the advantages and challenges of the ST Math program in the middle school, seventh and eighth grade.

Criteria for Participant Selection

The criteria employed for the selection of the participants include the following:

1. The teachers interviewed had to have at least 2 years' experience in the teaching of mathematics, knowledge of the ST Math program, contact with students in the ST Math program and knowledge of the data on student mathematics proficiency.
2. The administrator had to have at least 3 years of administrative experience, understanding of students' mathematics proficiency data and knowledge about the ST Math program.
3. The SIP leadership team facilitator had to have no less than 3 years of teaching experiences, knowledge of the ST Math program and understanding of the data on student mathematics proficiency. She is responsible for reviewing students' test data, report progress and determine progress and weaknesses.

Participants/Rationale for the Number of Participants

The participants for the study consisted of the three mathematics teachers, the school administrator, and the SIP leadership team facilitator from the middle-school. I have a small number of participants for the interview because the school is relatively a small school with few classes. Because of the size of the school and the limited number of mathematics teachers, there were limitations with respect to privacy of participation in the study. Similar to previous case studies that have been conducted with small sample sizes of teachers: Gamlem, (2015) 3 teachers while Kelly, Gningue, and Qian (2015) interviewed 4 teachers. I planned to deeply understand and explore a small sample – 3 mathematics teachers, the school administrator, and the SIP leadership team facilitator. The 3 mathematics teachers were for seventh and eighth grade respectively. One of the math teacher previously taught mathematics in the school but is currently teaching a different subject. Based on the idiographic interview focused method, this sample size should be enough. Creswell (2013) specified that a case study should not include more than four to five cases in a single study and that these numbers should be enough to provide sufficient themes. While Robinson (2014) pointed out that the sample size used for qualitative research is impacted by theoretical and practical issues. Interview research that pertains to the study of general or universal laws – nomothetic – focus on developing or testing general theory and so it has a large sample size. On the other hand, interview research that has an idiographic ideology utilizes a small sample size that is enough for the researcher to gather adequate information regarding the case and for a thorough examination of that case (Robinson, 2014).

Robinson (2014) suggested that researchers using Interpretative phenomenological analysis (IPA) are given the guideline of three-16 participants for a single study. He emphasized that "The lower end of the spectrum is for undergraduate research while the upper end is for larger-scale funded research" (p. 29). The reason is that it prevents the researcher from being weighed down by too much data and allows individuals within the sample to be given a defined identity. A case study research can equally be an N = 1 case study using an idiographic interview-focus. An example of such is Sparkes' (2004) research on Lance Armstrong (Robinson, 2014).

Relationship Between Saturation and Sample Size

The notion of saturation has been challenging for qualitative researchers as it is used by some to determine the sample size. There have not been specific rules regarding the application of saturation nor any tests that assess the sample size of a quality qualitative study (James, 2017). Saturation is described as the point of diminishing returns that is, a point that additional data will not yield further information regarding the research questions nor produce new themes or categories (Glaser & Strauss, 1967; Lowe, Norris, Farris & Babbage, 2018). Lowe et al, (2018) acknowledged that the sample size and data collected should provide ample opportunity to identify themes of the case as well as conduct triangulation of the data. Similarly, Creswell, (2013, 2015) emphasized that relying on one source of data is typically not enough to develop in-depth understanding of a phenomenon in a case study. This research utilized interview, documents, and reports. Five participants in three different roles are interviewed and archival documents which include student's ST Math pre/posttest scores and documented standardized test scores from the last five years are utilized.

To achieve saturation in this study, I conducted in-depth interviews with five participants who have adequate knowledge and information to address my research questions. Following the first interview, there were follow-up interviews as needed until I achieved saturation. I personally used a saturation table to document each theme in the data provided. Using the saturation table, enabled me to easily identify that later data did not contribute new themes (Lowe et al., 2018). Also, I utilized NVivo software to organize my themes and categories.

Instrumentation

Research instrumentations are measurement tools used for obtaining data of interest from the participants. According to Ghazali (2016) an instrument is only valid and applicable when it measures what it is intended or designed to measure. Rosenthal

(2016) emphasized that the researcher should thoroughly plan the data collection instrumentation that is suitable in answering the research question under study. In this study, data collection involved interviews of participants and the examination of archival documents – ST Math pre/posttest scores and recorded standardized test scores from the last five years. These instruments were sufficient to address the research questions. Elements of activity theory, cognitive theory and 21st century theory were evident in the data collection process as the interview protocol and questions were constructed to include the relevant constructs of the conceptual framework. For example, when the participants answer the interview question "How are the students using the program to master mathematics skills and concepts?" elements from the cognitive theory were evident.

According to Young et al., (2018) interview is used to extract information on specific issue from stakeholders who are knowledgeable in a particular field. It also enables researchers to focus on the participants' perspective regarding important or relevant issues. Rosenthal (2016) listed features of interview as include: interview protocol, collection or recruitment of participants, transcribing the interview script and analyzing important themes from the transcripts. Through interview, I extracted information, and gather the perspective of teachers and administrators on the advantages and challenges of implementing ST Math program in the seventh and eighth grade. Interview questions explored the teachers' and administrator perspectives as viewed through the lens of activity theory, of ST Math program as a multimedia human computer interaction program including how ST Math as an element of 21st century skill contributes to improving students' mathematics proficiency. For instance, the interview question on how ST Math as a multimedia 21st century skill technology program aid students' learning was analyzed and interpreted using the three theories.

The students' ST Math pre/posttest scores, and recorded standardized test scores were able to provide descriptive information to answer the question, what do students' test results indicate about the overall changes in students' test scores with the continuous implementation of the ST Math multimedia technology instructional program in seventh and eighth grade? It was also used to triangulate data from teachers' interviews about the benefits of ST Math. The use of these documents is evidence of the overall changes of continuous implementation of the program. It enabled viewing and obtaining information on students' previous and current mathematics proficiency level on the state standardized test scores since the implementation of the program and students' ST Math pre and posttest scores. This is visible in Appendix C.

The conceptual frameworks are associated with the two research questions. While the interview questions explore the teachers' and administrator perspectives as viewed through the lens of activity theory, cognitive theory and the 21st century theory, research question two deal with outcome of students' interaction with the artifact, the multimedia designed tool and the expected 21st century skill that is relevant to students learning. The interview protocols and metric for the archival data can be found in Appendix B and C. Table 1 provides an overview of the research and interview questions.

Table 1

Interview Questions and Research Questions

Research questions	Interview questions
RQ1: What are teachers' and administrators' perspectives of the advantages and challenges of implementing the ST Math multimedia technology game-based instructional program on students' learning and proficiency in mathematics in seventh and eighth grade?	What do you think about the ST Math program and the advantages of implementing it in the middle school? How does ST Math as a multimedia 21st century skill technology program contribute to students' mathematics skills and proficiency? How did the ST Math program affect students' attitude toward math? In your view, what are the challenges students face using ST Math, and what can be done to avert these challenges? What are the challenges teachers face implementing ST Math, and what can be done to avert these challenges? What suggestions do you have regarding how best to implement the program in the school?
RQ2. What do students' test results indicate about the overall changes in test scores with the continuous implementation of the ST Math software technology instructional program in seventh and eighth grade?	What is evident in students' mathematics test achievement as the use the ST Math program? What do you attribute to this success or lack of success? How do you think the continuation of the implementation of the ST Math program in the school has reflected in students' mathematics proficiency?

Table 2 summarizes an overview of the research design which include the research questions, framework, methods of data collection and analysis.

Table 2

Overview of the Research Design

Research questions	Framework	Method of data collections	Data analysis
RQ1: What are teachers' and administrators' perspectives of the advantages and challenges of implementing the ST Math multimedia technology game-based instructional program on students' learning and proficiency in mathematics in seventh and eighth grade?	Activity theory (Vygotsky, 1978) Cognitive theory of multimedia learning (Mayer, 2001) 21st century skills theory (Partnership for 21st Century Skills, 2006)	Interview	Open coding Descriptive code- one word capitalized code Coding for patterns, categorization, and themes Use of NVivo to organize into themes
RQ2: What do students' test results indicate about the overall changes in test scores with the continuous implementation of the ST Math multimedia technology instructional program in seventh and eighth grade?	Activity theory (Vygotsky, 1978) Cognitive theory of multimedia learning (Mayer, 2001) 21st century skills theory (Partnership for 21st Century Skills, 2006)	Interviews and document review (students' ST Math pretest and posttest scores and recorded standardized test scores from the last 5 years)	Use of descriptive analysis of finding the difference in the mean, median and mode Triangulation

Procedures for Recruitment, Participation and Data Collection

The participants for the study consisted of Midland Middle school three mathematics teachers, the school administrator and the SIP leadership team facilitator. I asked for a written permission from the school administrator to use the school as the setting for my research and to have access to the participants and data. I informed the research participants and school of the purpose, methods, benefits and intended possible uses of the research including participants' risk through debriefing procedures and sending of consent letter to them. A day was set aside to debrief the participant and at the same time seek their consent and willingness to participate in the interview. I asked the participants to provide two-time slots that are convenient for them to be interviewed. From these slots, I picked one. I informed the participants that the interview is voluntary. The interview involved face to face semi-structured interview and a phone interview. I allotted a minimum of 25 minutes for the interview. I taped the interviews to guarantee accuracy when transcribing. Also, I conducted a phone interview. After transcribing the interviews, I needed additional information regarding some questions, responses, and themes so I contacted the participants for a follow-up interview. I scheduled and conducted the follow-up interviews until I achieved saturation. Following, the participants received a copy of the interview transcript for validation before finalizing the research. At the end of the data collection, with sufficient data to answer the research questions, the participants were free to disengage from the research with a thank you note and a 20-dollar gift card offered by the researcher.

Related documents which included students' ST Math pre/posttest scores and documented standardized test scores from the last 5 years were collected from the school. I wrote to the school requesting them to provide me with the documents and validated the school record with the state report card on the state board of education website. For confidentiality purpose, the documents have no individual student's name. All the participants invited to take part in the research accepted the invitation and were interviewed.

Data Analysis Plan

Data analysis is the process whereby the researcher organizes, transform, categorize, interpret, and synthesize the data collected into relevant information that will support decision-making process (Hatch, 2002; Creswell 2015). Qualitative data analysis is the process of transferring qualitative data collected into some category of interpretation and explanation that will facilitate the understanding of the people and situations investigated. The interview data addressed research Question 1 while data from students' test reports answered research Question 2. Qualitative data analysis was applied in answering the research questions.

The first step for data analysis was to organize and prepare the data collected through typing up the audio and notes. Following, I read the transcript to get the general or whole idea. Afterwards, re-read again (Creswell, 2009, Creswell, 2017, Lauer, Brumberger & Beveridge, 2018, Moral, de Antonio, Ferre, & Lara, 2015). The next step was coding the transcript. Coding is the process of categorizing the data transcript into large pieces using the expression or words of the participant. Coding may be accomplished through deductive approach beginning from research questions, frameworks or previous research. On the other hand, coding may be done through inductive method such as the grounded-theory approach of open coding (Creswell, 2009, Creswell, 2017, Lauer et al., 2018, Moral et al., 2015). In this research, I began with the open coding and then proceeded to search association with the research questions and frameworks. Open coding was necessary because it enable me to break the data into chunks. The open coding involved the use of one-word capitalization descriptive code and coding for pattern. The descriptive words were turned into code maps, categories, and themes by grouping related words using the computer software NVivo. I generated five themes that appeared as my major findings to answering the research questions and interpreting the data (Creswell, 2009, Creswell, 2017). Also, the themes aligned with the conceptual framework.

More so, I performed an analysis for each of the research questions through coding, categorizing, attaching concepts, perspectives, and strategies to the categories to understand the advantages and challenges of students' participation in the program and their mastery or proficiency of the mathematics standards. I repeated the above steps for the follow-up interviews until all aspect of the research question was answered and saturation was achieved. These procedures were applicable to both the math teachers as well as the administrator and the SIP leadership team facilitator.

Using the students standardized test scores; I conducted a descriptive analysis of statistics to see what kind of descriptive change had occurred in the student proficiency level and the mean of the students ST Math pretest and posttest scores. I analyzed these documents to see if implementing ST Math in Midland Middle School has made any difference in students' mathematics proficiency and if the ST Math pretest and posttest scores indicated that students' participation in the program has made any differences from the start to the end of the school year. To resolve any discrepancy in the different data collected, I used triangulation, participant validation and the process of saturation.

Issues of Trustworthiness

Unlike quantitative studies that use validity and reliability to determine the trustworthiness of the research, qualitative studies establish trustworthiness through the ability of the research finding to be credible, transferable, confirmable and dependable. Credibility deals with the accuracy and truth of the research finding (Newman & Clare, 2016; Ngozwana, 2018). Transferability referred to the meaningfulness and applicability of the research to a similar situation, context, and population. Confirmability is the lack of bias or the degree of neutrality in the researcher's findings. The study must be established by the response of the participant and not influenced in any way by the researcher opinion or personal motivations.

Dependability in qualitative study is equivalent to reliability in quantitative research. It involves the evaluation of the quality of the process of data collection, data analysis and theory generation. It focuses on the explicitness and the consistency of the research findings if it is repeated by other researchers. A dependable study needs not only to be consistent, but also accurate. (Anney, 2014, Creswell, 2013; Newman & Clare, 2016; Ngozwana, 2018; Simon & Goes, 2016)

In this research, to maintain credibility, I used triangulation to show the research study's findings are credible. My data collection included interview with teachers and administrators and the use of archival data collected from the school. These data were triangulated. Also, I provided rationales for sample size, amount of data included in the study and rich description of the culture and context. The use of purposeful sampling can also contribute to the credibility of the research as well as participant check to ascertain that the information included is accurate. During data analysis, I collected enough data that answered the research question and attained saturation.

Transferability refers to the ability of the qualitative researcher to demonstrate that the findings of the research apply to similar settings, populations, situations, and related phenomena. I used full description to show that the research study's findings can apply to other contexts, circumstances, and situations by providing adequate information about the research background, participants, procedures, researcher-participant relationships, and self.

To ensure confirmability, I was neutral by providing an audit trail that highlighted every step of the data collection and data analysis. Lastly, I used triangulation to reach a consensus that the research process and the data analysis findings are consistent and could be repeated.

Ethical Procedures

Ethics in research pertain to better ways to eradicate incompetency, dishonesty, subjectivity, and lack of fairness in research. It is the morally good or correct practices in research (Creswell, 2013; Newman & Clare, 2016; Ngozwana, 2018). In qualitative research, ethical procedures should be evident in informed consent, withdrawal from the study, confidentiality, and anonymity (Newman & Clare, 2016; Ngozwana, 2018).

Before I began the research, it was vital to put into consideration the value or usefulness of the research to the population. the research study was worth doing because it aimed at providing an understanding of the usefulness of the ST Math program in improving student's mathematics proficiency. Various steps were taken to ensure the integrity and quality of the research. Some of those are listed above under trustworthiness. After my research committee approved the research proposal, I submitted it to the Internal Review Board (IRB) for approval. The IRB's responsibility is to protect the rights and safety of the human research participant. They also ensure that the possible benefits of the research outweigh the associated risks to the participants. IRB approved the proposal (IRB approval number 05-08-19-0426998).

Upon approval of the proposal, I asked for a written permission from the school administrator to use the school as the setting for the research and have access to the participants and data. The school administrator forwarded the request to carry out the study to the school superintendent who granted the request. The research participants and school were fully informed of the purpose, methods, benefits and intended possible uses of the research including participants' risk. There was minimum risk involved in the research. I ensured that the interview questions are devoid of words or language that will be upsetting or emotional harmful as well as reputational damage free. Also, I was sensitive to labels by respecting the participant and people involved with the research. Equally, I acknowledged all participants and used appropriate title for them. I made it clear to participants that the interview is voluntary. No incentives were provided, or coercion involved, but at the end of the data collection process, I provided participants with a 20 dollar thank you gift card for their time and input. These data were analyzed descriptively.

I remained independence and there was no conflict of interest or partiality throughout the research period. I did not let my opinion or point of view interfere with the accuracy of the collecting and reporting of the data. I also maintained confidentiality and anonymity of the participant by using codes when transcribing the interview data. The data were not excessive, but adequate, relevant, accurate and up to date. The data were not kept longer than is necessary. The interview audio and student data were stored in a locked-up file cabinet. On the computer device, it was encrypted, and password secured. I am the only person that has access to the data. Data were not transferable. Students' data and interview were coded and anonymized. Direct identifiers such as personal information – addresses and names were removed from the interview participant and student data. Pseudonyms were used instead. At the completion of the research, destroyed the data.

Summary and Conclusion

Students' inability to master mathematics skills in middle school has contributed to lack of proficiency in mathematics. Educators thereby seek for research-based curriculum to improve students' mathematics learning and proficiency. The research questions in this investigation addressed the advantages and challenges of the ST Math implementation in middle school by conducting a case study that allowed in depth exploration and data triangulation to better learn about the program. Teachers and administrative perspectives regarding the advantages and challenges of implementing ST Math in the middle-school mathematics and its contribution to students' proficiency in mathematics were ascertained. As well as the overall changes in students' test scores with the continuous implementation of the program.

Chapter 4 includes the research setting, participants' demographics, and recount of the process of data collection. I also share the results of the data analysis by discussing the codes and theme that emerged from the study based on the research questions and theoretical framework. The chapter concludes with evidence of trustworthiness.

Chapter 4: Results

The purpose of this qualitative single case study was to examine the advantages and challenges of implementing ST Math on students' learning and proficiency in mathematics in seventh and eighth grade. This purpose was accomplished by examining teachers' and administrators' perspectives of the program as a research-based curriculum that seeks to assist seventh and eighth-grade students in mathematics proficiency. Using semi structured interviews, I gained an in-depth understanding of the teachers' and administrators' perspectives of the advantages and challenges of using the ST Math program. I also descriptively examined what students' test results indicated about the overall changes in test scores when continuous implementation of the program was used in seventh and eighth grade compared to prior to its use. The following research questions were the foundation of the study:

RQ1: What are teachers' and administrators' perspectives of the advantages and challenges of implementing the ST Math multimedia technology game-based instructional program on students' learning and proficiency in mathematics in seventh and eighth grade?

RQ2: What do students' test results indicate about the overall changes in test scores with the continuous implementation of the ST Math multimedia technology instructional program in seventh and eighth grade?

In this chapter, I introduce the results of the study, describe the nature of the setting, present participants' demographics, and recount the process of data collection. Also, I discuss the codes and themes that emerged from the interview data as well as perspectives on activity theory, Mayer cognitive theory, and the 21st century skills theory, which were the foundation for this research. I report students' test results to determine overall changes in test scores with the continuous implementation of the ST Math program. Finally, I conclude the chapter with evidence of trustworthiness.

Setting

The setting for this study was a school in the southern United States. Midland Middle School is a Title 1 school with 63% of its students from economically disadvantaged homes. The school population consists of 230 seventh and eighth-grade students. Demographics data reveals that the student body is 99% Black with less than 1% Hispanic and White, and 55% of the population is female and 45% is male. State standardized test scores indicated that students in this school were below average in math proficiency. To acquire levels of proficiency, the ST Math program was purchased and implemented in the school for all students.

Demographics

I interviewed the school administrator, the SIP leadership team facilitator, and three mathematics teachers. The teachers I interviewed had at least 2 years of teaching experience in mathematics with no less than 5 years of teaching experience. One of the teachers was a previous math teacher now teaches a different subject. All three teachers have taught no less than four classes for both seventh and eighth-grade students in the last 2 years. The SIP leadership team facilitator has held the position for 10 years, and the administrator has served in that capacity for more than 10 years. All participants were

Black. They all knew about the ST Math program, had contact with students in the ST Math program, and had knowledge of the data on student mathematics proficiency.

For identification and to maintain confidentiality following ethical codes and IRB requirements, each participant was assigned a numerical pseudonym. The SIP leadership team facilitator was classified as an administrator to conceal the identification of having just one administrator; they are identified as Ad1 and Ad2. The three mathematics teachers are identified as teacher T1, T2, and T3. Table 3 highlights the participants' identification numbers, their roles in the school, and the range of years of teaching experience. To protect participants, no additional demographic information has been provided.

Table 3

Participants' Identification Numbers, Role, and Years of Experience

Participant number	Identification number	Role	Years of experience
Participant 1	T1	Teacher	10–15
Participant 2	Ad1	Administrator	10–15
Participant 3	Ad2	Administrator	10–15
Participant 4	T2	Teacher	10–15
Participant 5	T3	Teacher	1–5

Data Collection

Two sets of data were collected for this research. For RQ1, semistructured interviews were conducted to elaborate and provide answers. For RQ2, students' state standardized test scores and ST Math pretest and posttest scores were used. Before the onset of data collection, I received a signed letter of cooperation and data usage agreement from the research site. These documents were approved and signed by the school superintendent and forwarded to Walden IRB. Walden IRB approved the research, and the approval number is 05-08-19-0426998. Following Walden IRB approval, the data collection commenced.

The interview process began by e-mailing the letters of invitation to possible participants. Participants were selected from the setting based on purposeful sampling; they were individuals knowledgeable to provide insight into the specific situation under investigation. Next, I distributed consent forms that highlighted important information regarding the research to potential participants. All invited participants accepted to participate in the research and signed the consent form. Using e-mail and phone calls, I set dates for the interviews at the convenience and discretion of the participants. To ensure that participants were comfortable and felt safe to share, each was interviewed in a location of their choice. Various locations included a university library, university conference center, a school classroom, and a phone interview. All interviews took place in June 2019.

The semistructured interviews allowed for open-ended questions that aimed to encourage the participants to share their personal experience with ST Math with the possibility of probing the participants for further clarification. There were variations in the duration and number of interviews. Each original interview time ranged from 20–35 minutes with the option of a follow-up interview. The data were recorded using a Sony tape recorder and a cellphone recorder for backup. The phone interview was recorded using the ACR phone recording app. I personally transcribed each interview within 2 weeks. The transcribed interviews supported the need to carry out additional probing on some of the participants' response. Three participants were contacted for a follow-up interview. Two responded and the follow-up interviews were conducted. The follow-up interviews lasted 25–40 minutes using the same method previously indicated.

For the next phase of the data collection process, I obtained standardized tests scores from the school database and verified with the state department of education report card website. Students' tests scores data recorded for this study included the aggregate percentage of all students' proficiency level for seventh and eighth grade, before and after the ST Math implementation. Other test scores obtained for the research were the ST Math pretest and posttest. These test scores were obtained from the school ST Math program data website. Students' aggregate mean scores for seventh and eighth grade were recorded. The data from the 2 sources—interviews and test scores—were triangulated. Overall, the interview process and data collection were successful. No unusual circumstances were encountered during data collection.

Data Analysis

In analyzing the interview data, the researcher utilized the process of progressing inductively from open coding using one-word capitalization descriptive code to coding for patterns, categories, and themes. The first phase of analyzing the interview data was to transcribe the recorded interviews and organize them by assigning a number for identification purpose to each participant instead of a name. Following, I printed out the transcript and read it several times to get the general idea. After the reading I examined the transcripts line by line to capture the rich information from the interviews with each of the five participants. I began the coding process by applying open coding starting with the use of one-word capitalization descriptive code. I proceeded with noting for patterns, repetitive words, phrases, and notable sentences related to the phenomenon, research questions and conceptual framework that were repeated among the participants. Following the coding process, I identified some themes related to the research questions and conceptual framework. Progressing inductively from open coding to coding for patterns, categories and themes help me to narrow down the scope of the study and understand the interview data. With the general knowledge gained from the open coding, I moved on to use the NVivo software. The use of the NVivo software makes it easier to identify frequently used words during the interview, patterns, codes, identify themes, store, and retrieve data. Using the NVivo software, I generated participants frequently used words. These words were used to establish the codes and eventually the themes that emerged related to the research questions, conceptual frameworks, and key viewpoints in the literature review. The codes and themes generated using NVivo were compared to that of open coding. Figure 7 shows the frequently used words during the interview while Table 4 explains the coding and themes that emerged from the codes. Figure 8 shows example of coding related to technology usage.

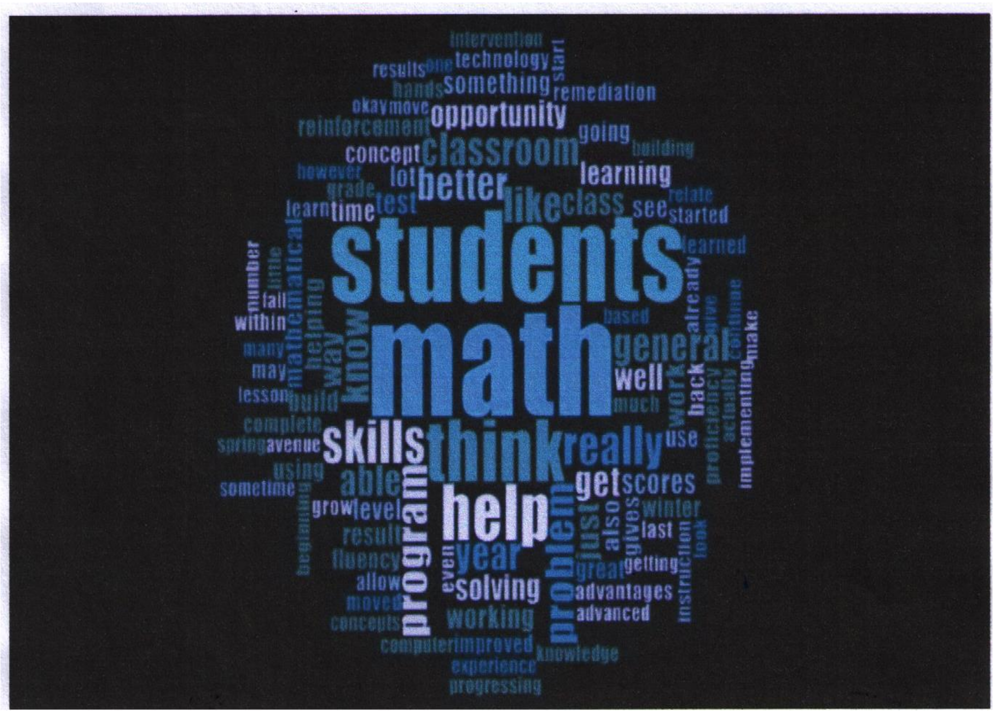


Figure 7. Frequently used words generated by NVivo.

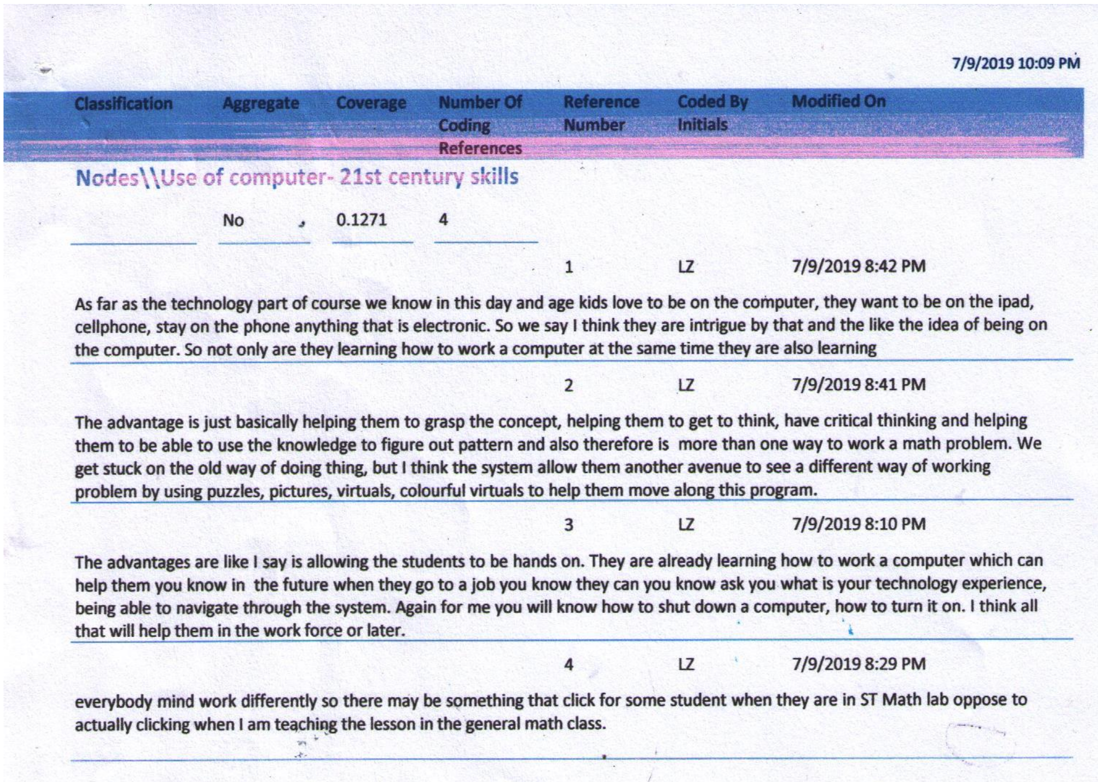
The frequently used words generated were turned into code maps, categories, and themes using the computer software NVivo. Table 4 explains the coding and themes related to the research questions and conceptual framework produced.

Table 4

Codes and Themes Related to the Research Questions and Conceptual Framework

Codes identified	Themes identified with RQ1	Themes identified with RQ2
Goals of ST Math Advantages of ST Math Students Teachers Best instructional practices Challenges to Students Teachers Administrator Students' attitudes Averting the challenges Technology usage Supplementary/remediation/ reinforcement/technology intervention/computer usage Visual learning Students' progress Students engagement Students motivation	Advantages Research-based program Better math fluency, critical thinking, and problem-solving skills Students experience success and growth/higher math scores ST Math as a remediation/supplementary /reinforcement tool Technology intervention, a different way of learning Students having technology experiences for the future Assist mathematics teachers to reduce students' mathematics remediation time Challenges Students' frustration Teachers' frustration Leadership team ensuring the proper implementation of the program Lack of verbal instruction Students' motivation and mathematics ability Classroom distraction Solutions Class size Class time Active monitoring Keeping them engaged Classroom management	Improvement in students' mathematics proficiency level Themes identified with conceptual framework Visual learning, (Mayer cognitive theory) Technology usage, intervention and interaction (21st century skills and activity theory). Examples of quotes related to improvement in students' mathematics proficiency level "Prior to implementing ST Math, we found out that a number of our students lack the fluency and rational numbers as it relates to fractions, decimal, percents and intergers and as a result of using ST Math many of our students have really started to grow those skills and that is evident in the many of the reports that are generated by the formative and summative assessment that we administer throughout the year."(T1)

The codes and themes that emerged from the data are related to the research questions and conceptual framework. They show the participants perception of the advantages and challenges of using ST Math. The codes and themes included both positive and negative implications. Below is an example of NVivo coding related to technology usage.



7/9/2019 10:09 PM

Classification	Aggregate	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Nodes\\Use of computer- 21st century skills

	No	0.1271	4			
				1	LZ	7/9/2019 8:42 PM

As far as the technology part of course we know in this day and age kids love to be on the computer, they want to be on the ipad, cellphone, stay on the phone anything that is electronic. So we say I think they are intrigue by that and the like the idea of being on the computer. So not only are they learning how to work a computer at the same time they are also learning

2 LZ 7/9/2019 8:41 PM

The advantage is just basically helping them to grasp the concept, helping them to get to think, have critical thinking and helping them to be able to use the knowledge to figure out pattern and also therefore is more than one way to work a math problem. We get stuck on the old way of doing thing, but I think the system allow them another avenue to see a different way of working problem by using puzzles, pictures, virtuals, colourful virtuals to help them move along this program.

3 LZ 7/9/2019 8:10 PM

The advantages are like I say is allowing the students to be hands on. They are already learning how to work a computer which can help them you know in the future when they go to a job you know they can you know ask you what is your technology experience, being able to navigate through the system. Again for me you will know how to shut down a computer, how to turn it on. I think all that will help them in the work force or later.

4 LZ 7/9/2019 8:29 PM

everybody mind work differently so there may be something that click for some student when they are in ST Math lab oppose to actually clicking when I am teaching the lesson in the general math class.

Figure 8. Example of NVivo coding related to technology usage.

As shown in Figure 7 above several codes and themes emerged. These codes help me to identify the concepts, narrow down the scope of the study, understand the interview data and find relationship between them. The themes that developed relate to the research questions as well as aligned with the conceptual framework and are important in answering the research questions because they highlight participants' account and perceptions that are significant and recurred several times during the interview and data set. Theme 1 was supported by 3 participants. Theme 2 by 4 of the participants while Theme 3 was agreed upon by all the participants. Equally, all participants upheld Theme

4. In contrast, Theme 5 highlights the challenging aspect of the program. All participants attest to the fact that students, teachers and administrators are frustrated regarding some aspect of the program. Below are the identified 5 themes selected to address research Question 1 about the advantages and challenges of implementing ST Math:

1. ST Math is a research-based program
2. Students have experience success and growth using ST Math
3. ST Math as a remediation/supplementary/ reinforcement tool
4. ST Math offer students a different way of learning through technology application.
5. Students', teachers' and administrators' frustration due to students' lack of motivation, mathematics ability, classroom distraction, class size, and lack of verbal instruction.

The following paragraphs give a detailed discussion of the participants perspective regarding the themes.

Students' Test Scores

To address the second research question regarding the overall changes in students' tests scores with the continuous implementation of the ST Math beyond a single school year. Two different test scores were utilized. The first test is the state mathematics assessment that provides information about student learning in each grade level. It determines the students' knowledge in mathematics and measure student's ability to meet the state's mathematics academic standards. Total student's mathematics proficiency in each grade level is calculated in percentages. The total number of students that participated in the state assessment for each year shows 257 students for the 2013/2014 school year, 249 in 2014/2015 and 246 in 2015/2016. During the 2016/2017 school year we had 232 students while in 2017/2018 there were 222 students. These number is further reflected in Table 5 below.

The second test is the ST Math pretest and posttest. These tests were designed to measure the amount of learning the students have assimilated throughout the course of the ST Math program. Students mean scores for seventh-grade pretest and posttest were derived from the sum of all seventh-grade pretest and posttest respectively divided by the total of students who took the test. Same formula was applied to eighth-grade pretest and posttest to obtain the mean of the ST Math pretest and posttest. The number of students that participated in the ST Math program for the 2017/2018 school year were 218 while we had 230 students in 2018/2019.

Using the above discussed 2 test scores, a descriptive analysis was conducted to see what kind of descriptive changes had occurred in the students' mathematics Proficiency level with the continuous use of the ST Math program beyond a year period. For the state assessment, total student's mathematics proficiency in each grade level is calculated in percentages whereas the ST Math students mean scores for both the pretest and posttest were calculated by dividing the sum of all seventh-grade pretest and posttest respectively with the total number of students who took the test. Same formula was applied to eighth-grade pretest and posttest to obtain the mean.

Information regarding students test scores were collected from the school database and confirmed with the state department of education report card website report.

The seventh and eighth-grade students' proficiency level from 2014 through 2018 were examined to find out the overall changes in students state standardized test score as shown in Table 5 and 6. The state standardized test was paper based until 2018 and 2019 when it became computerized. Also prior to 2018, the test was taken annually, but in 2018 and 2019, the test was taken 3 times in a school year – Fall, Winter and Spring. The Fall and Spring test is usually compared to uncover students' growth and overall proficiency level. Using the students standardized test scores; a descriptive analysis of the test scores was conducted to see what kind of descriptive changes had occurred in the students' mathematics Proficiency level of the state standardized test score prior to implementation (2014/2015) and Proficiency level after implementation 2016-2019. Table 5 indicates students' proficiency level for before and after the ST Math implementation while Table 6 grouped students' proficiency level test results into cohort. Also, the information presented in Table 5 is further represented in Figure 10 in the result section.

Table 5

Mathematics Proficiency Level Prior to (2014 and 2015) and After Implementation (2016–2018), Percentages

	2013/2014	2014/2015	2015/2016	2016/2017	2017/2018
7th grade	7.8	8.1	7.9	11.5	9.7
8th grade	2.1	6.2	5.1	3.3	19.8
Total students	257	249	246	232	222

The information presented in Table 5 and represented in Figure 10 in the result section is further grouped into cohort and presented in Table 6.

Table 6

Mathematics Proficiency Level Prior to (2014 and 2015) and After implementation (2016–2019), According to Cohorts, in Percentages

Cohort 1			Cohort 2		
Grade	Year	Test Scores	Grade	Year	Test Scores
7th grade	2013/2014	7.8	7th grade	2014/2015	8.1
8th grade	2014/2015	6.2	8th grade	2015/2016	5.1
Cohort 3			Cohort 4		
Grade	Year	Test Scores	Grade	Year	Test Scores
7th grade	2015/2016	7.9	7th grade	2016/2017	11.5
8th grade	2016/2017	3.3	8th grade	2017/2018	19.8

ST Math Pretest and Posttest

As indicated previously, the research data also include a descriptive analysis of ST Math pretest and posttest to determine students’ aggregate mean score for the 2017/2018 and 2018/2019 school years as indicated in Table 7 and 8. At the beginning of each school year, before participating in the ST Math program, students take the pretest and their scores are registered. Both the ST Math pretest and posttest are computerized. The ST Math pretest and posttest were obtained from the school ST Math program data website and the test scores indicate whether the students’ participation in the program had made any difference from the start to the end of the school year. Students mean scores for seventh grade pretest and posttest were derived from the sum of all seventh-grade pretest and posttest respectively divided by the total of students who took the test. Same formula was applied to eighth-grade pretest and posttest to obtain the mean of the ST Math pretest and posttest. Table 7 provides a qualitative description of the aggregated mean scores of ST Math pretest and posttest. Table 7 is further represented in Figure 11 in the result section.

Table 7

Qualitative Descriptive Analyses of Students' Aggregate Mean Scores of ST Math Pretest and Posttest

	2017/2018		2018/2019	
Grades	Seventh	Eighth	Seventh	Eighth
Number of students	101	117	117	113
Pretest (mean)	52	66	50	68
Posttest (mean)	68	75	71	78

Table 7 is further broken down into cohort in Table 8. To enable a better understanding of the aggregate mean score differences between the same group of students while in seventh grade and eighth grade respectively.

Table 8

Qualitative Descriptive Analyses of Students' Aggregate Mean Scores of ST Math Pretest and Posttest, According to Cohort

	2017/2018	2018/2019
Grades	Seventh	Eighth
Number of students	101	113
Pretest (mean)	52	68
Posttest (Mean)	68	78

Understanding and detailed information concerning the tables is elaborated and discussed under results in addition to triangulation with the data from the interviews.

Discrepant data

In answering the questions, there were few discrepancies in the data. Discrepancy in data occurs when a participant has a different viewpoint from the main body of evidence. An area of discrepancy in the data is in the area of growth and progress.

Although most of the participants asserted that ST Math has contributed to students' mathematics growth and proficiency, one of the participants maintained that it had not made any difference in students' mathematics proficiency. Also, majority of the participants were of the opinion that students should spend more time on the ST Math program, but two of the participants suggested that the class time should be broken down into 30 minutes instead of the 1-hour spend each class period. The last discrepancy is regarding students that finished the program early. While some participants consider it as an achievement, one of the participants sees it as a distraction. The different viewpoints regarding the discrepancy will be discussed in detail under the result.

Evidence of Trustworthiness

Qualitative studies establish trustworthiness through the ability of the research finding to be credible, transferable, confirmable and dependable (Newman & Clare, 2016; Ngozwana, 2018; Simon & Goes, 2016). Below is a description of how I maintained the above qualities of trustworthiness in this research.

Credibility

To ensure that the research is credible I utilized purposeful sampling, triangulation, member checking, follow-up interview and adherence to the Walden University guidance. The research data include interview, students' standardized test score data, and ST Math pretest and posttest scores. These 3 data were triangulated for validation of the study. Participants for the interview were recruited through purposeful sampling to guarantee accuracy of the data since they are knowledgeable in the area of the research. Also, the students' standardized test score data were retrieved from the school database and confirmed by checking the state standardized test scores report card website making the data credible. Equally, I gave the transcribed interview back to the participants for review; therefore, ascertaining that the information included is accurate. Additionally, I strengthened the data collected by conducting a follow-up interview to clarify and further probe participants on some previous comments. Lastly, the adherence to Walden University IRB guidelines during data collection contributed to quality of credibility of the research.

Transferability

I ascertain that the research is meaningful and that the research findings can be applicable to similar situation, context and population by providing detailed description of the research background, participants, procedures, researcher-participant relationships, and self; therefore, providing detailed description whenever it was possible without jeopardizing confidentiality.

Dependability

Dependability focuses on the explicitness, consistency and accuracy of the research findings if it is repeated by other researchers (Newman & Clare, 2016; Ngozwana, 2018; Simon & Goes, 2016). The quality of dependability was built into the research during the process of data collection, data analysis and theory generation; therefore, contributing to different interpretations of the data. I described the research steps from the beginning to the end. The interview questions shared in Appendix B were created to align with the research questions and research theories as well as documented observation of each participant’s mood, body language and any occurrences during the interview. Also, data from the school validate data retrieved from the state report card website. All of the above improved the dependability of the research.

Confirmability

To ensure confirmability of the research, I made certain that the research is free of bias in the findings. The study was established by the response of the participant and was not influenced in any way by my personal opinion or motivations. Also, I kept a record that highlights every step of the data collection and data analysis process.

Results

The 5 participants provided thick description by responding to the interview and probing questions related to their perception of the advantages and challenges of ST Math program. The first part of the result section, which addresses the first research question, focuses on the results generated from the teachers and administrators' interviews. The second part of the results section addressed the second research questions and is centered on the qualitative analysis of the students test scores that were analyzed descriptively and allowed for triangulation. The results are discussed within the context of the research questions. A summary of the themes and related quotes are outlined below in Figure 9 while a detail narrative of the participants perspective regarding the themes is discussed below.

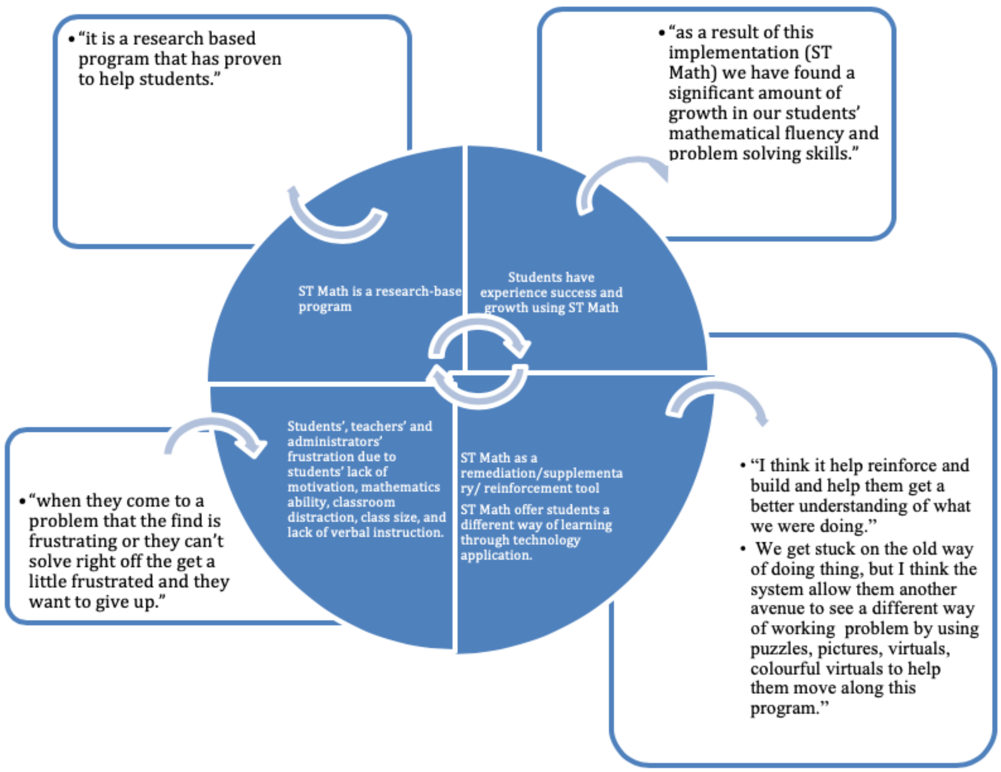


Figure 9. Examples of quotes related to the themes.

As discussed above, 5 themes emerged to answer the research Question 1: (a) ST Math is a research-based program; (b) Students have experience success and growth using ST Math; (c) ST Math as a remediation/supplementary/ reinforcement tool; (d) ST Math offer students a different way of learning through technology applications; and (e) Student, teacher, and administrator frustration occurs due to students' lack of motivation, mathematics ability, classroom distraction, class size, and lack of verbal instruction. Each of these themes was discussed using qualitative narrative.

The first quote associated with Theme 1 was directly supported by 3 of the participants. For Theme 2, 4 of the participants absolutely agreed to the statement. All the participants agreed that ST math is a supplementary program that provide remediation and reinforcement. In lieu of Theme 4, all participants unswervingly supported the statement. While Theme 1-4 deals with the positive/ advantages of the ST Math program, Theme 5 highlights the challenging aspect of the program. All participants attest to the fact that students, teachers and administrators are frustrated for the above listed reasons. As mentioned earlier the following paragraphs give a detailed discussion of the participants perspective regarding the themes.

Research Question 1

The first research question was, what are teachers' and administrators' perspectives of the advantages and challenges of implementing ST Math multimedia technology game based instructional program on students' learning and proficiency in mathematics in seventh and eighth grade?

Five themes emerged analyzing the interviews. Four themes are associated with the advantages of implementing ST Math and the fifth is related to challenges. Subcategories under advantages were research-based, students' progress and growth, students' engagement, remediation, supplementary, and reinforcement. Sub-categories under challenges were students', teachers' and administrators' frustration, lack of verbal instruction, students' motivation, mathematics ability, class distraction, class time and class size. Each of the themes is discussed below using qualitative narrative.

Theme 1: ST Math is a Research-Based Program

All the teachers and administrators agreed that the program was chosen and implemented in the school because it was a research-based program that the superintendent and stakeholders explore and found to be a useful in promoting students' learning and mathematics proficiency. Discussing from a teacher point of view, T1 commented:

> It is a research-based program that has proven to help students….in California and as a result of all the great things it has done for students in California, our superintendent felt it will be a great fit for the students here.

In like manner, one of the administrators, Ad1 remarked "ST Math was chosen because of the research that was done behind the program and it has been identified as a program that worked in helping the students." Ad 2 added:

> We looked at our results and we found that our scores reflected a need for math intervention. We searched around for different programs and ST Math just happened to be one that not only approach it as concrete type program, but it was also something that will let the children start concretely thinking about the math concepts. It also gave them a different way of doing the things that they are already doing in the regular math class.

Theme 2: Students have Experience Success and Growth using ST Math

Since the goal of integrating ST Math was to support student proficiency growth in math, it was important to learn how the participants in this study perceive the contribution of ST Math to students. The teachers and administrators acknowledged that ST Math program enhances students' mathematics skills, growth and proficiency except T2 who is skeptical about students' progress. T2 accentuated:

> I recalled students increased on the scantron math test maybe about 6% so that is not a whole lot, but I know is showing growth. I don't feel that ST Math you know is really playing a major role in students' achievement on test.

On the other hand, T1 commented "as a result of this implementation (ST Math) we have found a significant amount of growth in our students' mathematical fluency and problem-solving skills." Similarly, Ad2 noted

> What is evident is that they are progressing. They are not just stagnant, even if a child goes up 1%, they are progressing. It is showing that they have learned something that year and so using ST Math I think it help them … because they are getting not only their regular math but they are getting ST Math as an intervention type.

Not only does ST Math assists with the standardized test scores but also with the regular mathematics class test. T3 explains further:

> Even with them taking just the test in the classroom, the scores were better. If I gave them a quiz at the beginning or maybe at the middle part of the lesson and they do so well on it, by the time we get to the actual chapter test the scores were better and you can tell that they understood a little bit better what was going on. So again, the reinforcement in ST Math quite possibly help them make that test scores.

Although the teachers and administrators agreed that ST Math has contributed to students mathematics proficiency, results from the students' state standardized test scores as indicated in Tables 5, 6 and Figure 10 shows that there is no progress in students test scores for the first 4 years until in 2017/2018 when there was growth of 8.3 in students test scores. In contrast, qualitative descriptive analyses of the students' aggregate mean score of ST Math pretest and posttest as indicated in Table 7, 8 and Figure 11 shows that there is progression and growth of more than 10 points in students' learning. Also, when the same students moved from seventh grade to grade eighth their scores increased.

Theme 3: ST Math as a Remediation/Supplementary/ Reinforcement Tool

ST Math is used to provide students with supplementary mathematics instruction to close gaps and promote proficiency in mathematics skills. To this regard all teachers and administrators agreed that ST Math offers remediation/ supplementary tool and reinforces students' mathematics learning and proficiency. T1 observed:

> ST Math in the middle school would first of all allow mathematics teachers the opportunity to have certain students receive remediation without having the remediation take place in their classroom so that the students who are already fluent in those areas don't have to wait or postpone learning new ideas and concepts because other students within that class don't have the prerequisite skills for those topics that are discussed in the class. So, as a result, the remediation takes place in ST Math as opposed to the general ed classroom.

T2 added "is based on what they should already know, but also reinforcement of maybe some areas that they are struggling in." T3 contributed that "I think it help reinforce, build and help them get a better understanding of what we were doing." Ad1 voiced concern:

> We have a lot of students who have a deficit with math skills such as fractions, adding, subtracting three-digit numbers and working with the foundational concept that the ST Math program exposes the students to." While Ad2 pointed out that "they're able to work on ST Math constantly. Is not just I worked on it today and I will get it next day or the day after. Is every day they are focusing on those skills…

Theme 4: ST Math offer Students a Different Way of Learning through Technology Application

Both the teachers and administrators agreed that ST Math offer students the opportunity to interact visually with technology. It enhances students' knowledge and proficiency in mathematics as they learn with technology. Also, interaction with technology prepares students to be technology literate; therefore, preparing them for a technological driven work force. T2 explained:

> Generational [x (z)] they are all about technology. iPads, cell phones and anything that is technology based. So, I think it gives them more a hands-on opportunity to learn and with them using technology, computers or iPads, it may encourage them to stay within the program and to continue to work.

In the same view, T3 commented on the important of students engaging with technology for learning:

> The advantages are like I say is allowing the students to be hands on. They are already learning how to work a computer which can help them you know in the future when they go to a job you know they can you know ask you what is your

> technology experience, being able to navigate through the system. Again, for me you will know how to shut down a computer, how to turn it on. I think all that will help them in the work force or later.

Similarly, T3 made this significant comment:

> The advantage is just basically helping them to grasp the concept, helping them to get to think, have critical thinking and helping them to be able to use the knowledge to figure out pattern and there is more than one way to work a math problem. We get stuck on the old way of doing thing, but I think the system allow them another avenue to see a different way of working problem by using puzzles, pictures, virtual, colourful virtuals to help them move along this program.

Theme 5: Students, Teachers and Administrator's Frustration and Challenges

Participants in this study acknowledged that the major challenge of the students learning with ST Math is outright frustration as a result of students' lack of motivation, mathematics ability, classroom distraction, class size, class time and lack of verbal instruction. Students are frustrated of their inability to complete certain part of the assignment as a result of their lack of motivation and mathematics inability, so they get easily frustrated. Teachers and administrators acknowledged that this issue is one of the biggest problems encountered by the teachers. According to T3 these students "coming into seventh grade … do not have the understanding or know how to work the steps in multiplying 4-digit numbers or long division" therefore, as stated by Ad2 "When they come to a problem that the find is frustrating or they can't solve right off the get a little frustrated and they want to give up."

In addition to students' frustration, classroom distraction is another challenge mentioned by the participants. T3 commented "The challenges that students face will mainly be the distraction of others. You know they get distracted by their peers." Also, T2 and T3 mentioned that students find it difficult to be engaged with ST Math for a longer class period and were constantly complaining of the class time. T2 affirmed "is just being able to stay focus for so long, sitting and working on the program for 50 minutes. Equally, Ad1, Ad2, and T3 talked about the class size emphasizing the number of students in the class. Ad2 stressed "we have a large class like the number we had this past year. We had classes that are 32."

Teachers and administrators admitted that they are equally frustrated when students come into seventh and eighth without attaining grade level mathematics skills and believe that mathematics is a difficult subject thereby not trying but want the teacher to give them the answers. T3 explained:

> The biggest challenge is the students already having a perception that math is hard so since they have that perception is kind of hard. You should spend a lot of time trying to break that barrier because if they continue to have that barrier it makes it a little difficult for them to actually concentrate and grasps the concept that you are teaching.

Likewise, the administrators acknowledge that one of their challenges is ensuring that every student uses and participate in the program.

Possible Solutions to Some of the Challenges

Possible solutions to some of the challenges were also identified. Among these were assigning an aid to the ST Math computer lab to support the facilitator or reducing the class size, use of a headphone to block out noise, change in the class schedule and different incentives should be put in place to motivate students to continue to participate in the program. T3 recounted “I think that in the program as I was saying earlier if they will break it up into smaller group the teacher and whoever is assisting could better serve them in going over and explaining the lesson.” Ad 2 reiterated:

> If we have an aid in there especially when we have a large class like the number we had this past … that is one way we can help with the challenges because that one facilitator can’t be everywhere at least having someone else in there during that times can help alleviate some of that frustration and keep them on point, keep them engaged.

Student Test Scores

The second part of the results analysis centered on the students’ tests scores. Two types of students test scores were collected and utilized in this research. The first set of test scores is the state standardized test score that all seventh and eighth-grade students in the state are expected to take. The second students’ test scores are the ST Math pre and posttest scores. All seventh and eighth-grade students are expected to take the pretest before beginning the ST Math program to determine their level of mathematics proficiency while the posttest is administered at the end of the year to verify how much progress they have made in mathematics throughout the school year. Both types of students' test scores aim at descriptively answering research question two.

Research Question 2

The research question 2 was: What do students' test results indicate about the overall changes in students' test scores with the continuous implementation of the ST Math multimedia technology instructional program in seventh and eighth grade? Information regarding students test score data were collected from the school and the state department of education website. The seventh and eighth-grade students' proficiency level for 2014 through 2018 were examined and outlined in Table 5, 6 and Figure 10.

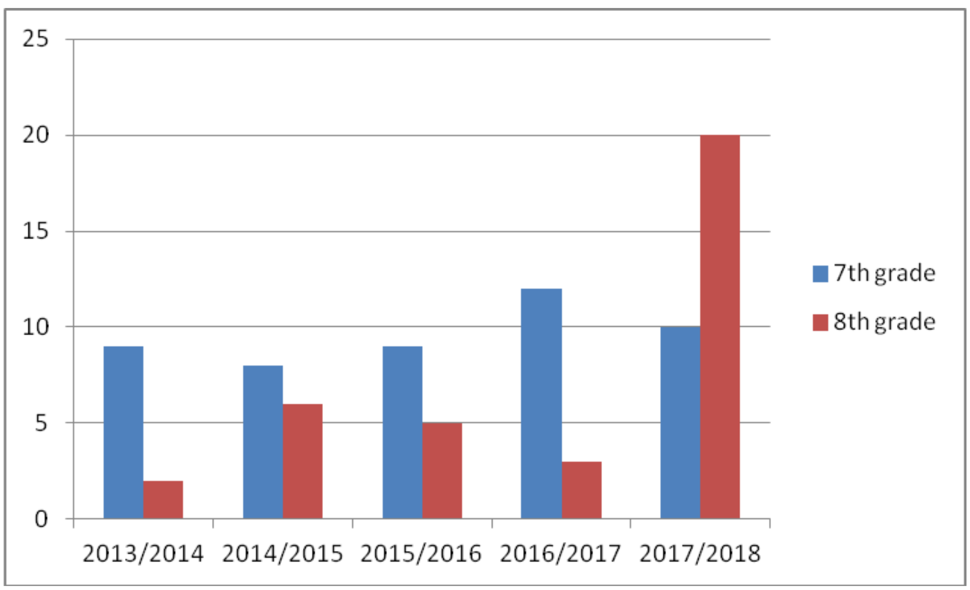


Figure 10. Mathematics proficiency level prior to implementation (2014 and 2015) and proficiency level after implementation (2016–2018).

Looking at the mathematics proficiency level Table 5, 6 and Figure 10, prior to implementation of ST Math 2013/2014 and 2014/2015 the level of mathematics proficiency went down in eighth grade. After the implementation of ST Math for 2 years, the same trend existed until 2017/2018 school year. Eighth-grade students had an increase of 4% in 2014/2015, dropped in 2015-2017 and a significant growth of 17 % in 2017/2018 school year. For seventh graders, throughout the years there was no trend indicating consistency in the test scores. Seventh-grade students have slight growth of 4% in 2016/2017 and then regression of 2% in 2017/ 2018. Table 6 shows four cohorts of the same students test scores while in seventh grade and eighth grade. There was decrease in the students' test scores in eighth grade from 2013/2014 to 2016/2017, but an increase of 8.3 % in 2017/2018.

In contrast to the mathematics proficiency level tables, Table 7, 8 and Figure 11 show the qualitative descriptive analyses of the students' aggregate mean score of ST Math pretest and posttest. Students mean scores indicate a steady increase or progress of an average growth of 10 points from the aggregate mean score of the pretest to the aggregate mean score of the posttest. When the same set of students moved from seventh grade to eighth grade there was an increase in the scores as further shown in Table 7.

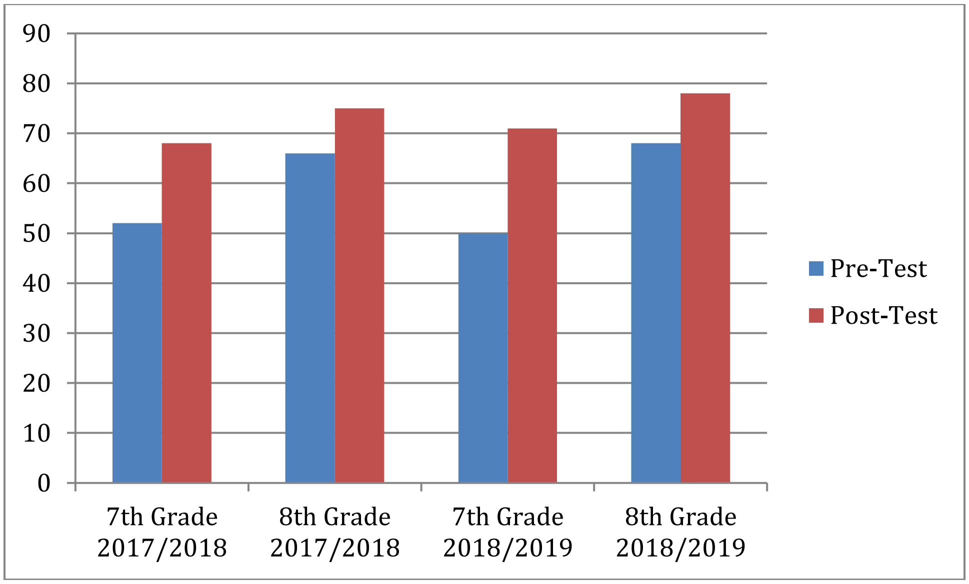


Figure 11. Qualitative descriptive analyses of students' aggregate mean scores of ST Math pretest and posttest.

Discrepant Data

As stated earlier, there were few discrepancies in the data. One area of discrepancy in the data is in the area of growth and progress. Participants agreed that ST Math has contributed immensely to students' mathematics proficiency level, but one was of the view that the program is not making much impact on students test in these words:

> Like I said before, I really don't see where the program is making a major huge impact on test proficiency because like I said the last time I if I recall correctly there was only 6% growth and that is for the entire student body so I don't think it is really reflecting on the students' performance. I don't think it plays a major factor."

On the other hand, another commented:

> Prior to implementing ST Math, we found out that the number of our students lack the fluency and rational numbers as it relates to fractions, decimal, percents and intergers and as a result of using ST Math many of our students have really started to grow those skills and that is evident in the many of the reports that are generated by the formative and summative assessment that we administer throughout the year.

While participants agreed that ST Math had contributed immensely in enhancing students' mathematic proficiency, examination of students standardized test score shows fluctuation in students' proficiency level over the years.

Also while majority of the participants were of the opinion that students should constantly be working on ST Math, one of the participants commented "I do not feel as if the students should be scheduled to go to ST Math class on a daily basis or every other day basis. I think it should be something that is done maybe once a week."

Another discrepancy is regarding students that finished the program early. While some participants consider it as an achievement, one of the participants sees it as a distraction, observing:

> However, I think the weaknesses of the program is just when the kids finish what else is there for them to do … what about those who finish the program before the end of the school year. I think it could be a distraction or it could be a benefit to encourage other students to complete the program.

In contrast, one of the participants said:

> I like the fact that you start on if it's something you don't know you learn it and then you move on to the next level. And I think that is the advantages because even our highest students are, I think most of the time our highest students finish the program within two to three months, and they are finished. So, it meets them where they are, or they start and are able to finish and it moves them up.

Summary

In this chapter, I discussed the data collection process, transcription of data, and data analysis as regards to each of the research questions. The results generated from the interview were presented as a qualitative narrative to recount teachers and administrators' perception of the advantages and challenges of using ST Math in the middle school. The advantages of using ST Math listed include ST Math is a research-based program that promotes students' mathematics growth and proficiency, engages students in remediation, and reinforces the mathematics concepts learned in the general mathematics classroom through technology applications. The challenges involve students', teachers' and administrators' frustration as a result of lack of verbal instruction, students' motivation, mathematics ability, class distraction, class time and class size. Possible solutions to the problems were also identified as ensuring that class size is reduced to smaller groups to enable the facilitator assist individual students and if retaining larger size of class, an aid should be assigned to the ST Math computer lab to support the facilitator. Also, students should be encouraged to use a headphone to block out classroom distractions. Besides, the class time should be broken down to a maximum of 30 minutes since it is difficult for some students to stay on task for long and different incentives should be put in place to motivate students to continue to participate in the program. The standardized test results show no progress until after the fourth year of implementation while the ST Math pretest and posttest mean score indicate progress.

Chapter five discusses the interpretation of the data results and reflects on the connection of the data with the research questions, conceptual frameworks and previous literature. It also explores the implication for social change, the research limitations and recommendations for future research.

Chapter 5: Discussion, Conclusions, and Recommendations

Teaching and learning mathematics in middle school can be a challenge for students and teachers. Nonetheless, the methods of instruction that teachers use can alleviate some of the challenges and improve students' mastery of the subject. Technology programs, such as ST Math, have been recommended to promote student proficiency in mathematics, but the program's advantages and challenges in middle school had not been examined. The purpose of this qualitative single case study was to learn about teachers' and administrators' perceptions of the advantages and challenges of implementing ST Math and to descriptively examine what student test results indicate about overall changes in test scores when continuous implementation of the program is used compared to prior to its use. *Continuous use* in this research refers to beyond a single school year: seventh and eighth grade. Through this study, I was able to discover that although ST Math is advantageous in improving students' mathematics proficiency, students, teachers, and administrators must unify to overcome challenges and to take advantage of the benefits of the program.

The conceptual frameworks applied to this study were Vygotsky's activity theory, Mayer's cognitive theory of multimedia learning, and the 21st century skills theory. The theories contribute to making the learning process easier by establishing how to successfully incorporate technology during instruction, enhance student learning and achievement, and create a guideline of a conducive interactive environment where students are actively involved and learning by doing, communicating, and receiving feedback.

The research suggests that class size, class time, use of headphones, and incentives should be considered to enhance the use of the program in the classroom. The challenges involved in the implementation of the program need to be rectified to maximize the learning outcome. The advantages indicate that ST Math can assist students in mastering mathematics concepts, and it should continue to be implemented in the school.

In this chapter, I summarize and interpret key outcomes of the study. The interpretation of the findings is related to the research questions as well as the conceptual framework and literature. I discuss the limitations of the research, offer recommendations for further research, and identify potential implications for social change.

Interpretation of the Findings

In this study, I examined teachers and administrators' perceptions of the advantages and challenges of the ST Math program. The interview results showed that teachers and administrators in Midland Middle School recognize the need for supplemental methods to enhance mathematics proficiency; subsequently, ST Math was implemented in the school. They agreed that ST Math is a research-based program that promotes students' mathematics growth and proficiency. It is also a remediation and supplementary reinforcement tool that offers students a different method of learning mathematics through technology. Nonetheless, the program is challenging in various aspects. The challenges listed by the participants of the study include student, teacher, and administrator challenges as a result of frustration originating from students' lack of motivation, mathematics ability, classroom distractions, class size, and the program's lack of verbal instruction.

Students' standardized test results show fluctuation in the test scores in the first 4 years of implementation in the school. There was positive growth of 8.3 in student test scores in 2017/2018. This positive outcome may be attributed to ST Math being fully implemented in both seventh and eighth grades as oppose to seventh grade alone. Prior to the 2016/2017 school year, only seventh-grade students came to the ST Math computer lab to participate in the program. Eighth-grade students depend on extra time, mentoring, and intervention time to login into the program. The ST Math pretest and posttest maintained an average growth of 10 points.

Alignment to the Literature

The results of this study confirm previous research that indicated teachers and administrators recognized ST Math as a nontraditional method of teaching and learning mathematics (Levi et al., 2016; Nisbet & Luther, 2014; Park & McLeod, 2018; Rutherford et al., 2014; Working, 2018). ST Math uses technology tools and a nonverbal approach to facilitate a change in learning. It shifts from the traditional teacher-centered paradigm to a student-centered model and provides significant independence that enables learners to establish how, when, and where to study (Eronen & Karma, 2018).

Further, my research supported the findings of Chappell et al. (2015), Arnord et al. (2015), and (Drijvers, 2015) that technology-supported programs enhance students' learning. Teachers and administrators assert that ST Math promotes students' mathematics proficiency; however, results from state standardized test scores show no positive growth in the first few years—only with continuous usage, beyond 1 year, was there an increase. At the same time, students' ST Math pretest and posttest aggregate mean scores showed an average of a 10-point increase. The disparity in students' achievement in both tests may be because the ST Math pretest and posttest are school-based, and students may not be under the duress of testing as they are with standardized testing. Standardized testing aligns with state law, and any school that does meet the requirement is labeled "in need of improvement" or a "failing school," and in some cases, the school is restructured (Bae, 2018; Balenlyne & Varga, 2016; Polikoff et al., 2017; Stotsky, 2016).

The teachers and administrators present students' frustration, lack of motivation, mathematics ability, classroom distractions, class size, class time, and lack of verbal instruction as the challenges for implementing the ST Math program. Nelson et al. (2016) and Onal and Demir (2017) determine that a number of students find mathematics difficult, boring and suffer from fear and failure of the subject especially if they have not mastered the elementary school mathematics curriculum before middle school (Nelson et al., 2016; Onal & Demir, 2017).

The conceptual frameworks for this study are the activity theory of Vygotsky (1978), the cognitive theory of multimedia learning of Mayer (2001), and the 21st century skills theory (Partnership for 21st Century Skills, 2006). The finding from this research aligned with the activity theory that maintains that as learners interact with the tool, technology, learning is bound to take place (Venkat & Adler, 2008; Vygotsky, 1978). Students interact with ST Math using technology tools such as iPads, desktop computers, and laptops. Mayer’s cognitive learning is based on the principle of visual learning. The finding from this study revealed that students interact visually with ST Math using puzzles, pictures, virtuals, colorful virtuals to help them move along in the program instead of words and numbers (Kuzu et al., 2007; Mayer 2001; Mayer et al. 2004). Lastly, the 21st century skills emphasized the importance of technology enhancing students’ knowledge, students’ engagement, and preparing them for the real world (Partnership for 21st Century Skills, 2006, Redmond, 2015, Tucker, 2014). The teachers and administrators agree that as students interact with ST Math, it prepares them for the workplace and contribute to their computer literacy.

Students’ standardized test results shows fluctuation in the test scores in the first four years of implementation of the program in the school. Only in 2017/2018 school year was there a positive growth of 8.3 in students’ test scores. This positive outcome may be attributed to ST Math being fully implemented in both seventh and eighth grades as oppose to seventh grade alone. Prior to the 2016/2017 school year, only seventh-grade students came to the ST Math computer lab to participate in the program. Eighth-grade students depend on extra time, mentoring and intervention period to login into the program. Equally, students’ lack of motivation, mathematics ability, classroom distraction, and frustration may be other factors. The ST Math pretest and posttest maintained an average growth of 10 points.

Limitations of the Study

As previously stated, this study focuses on a specific program (ST Math) using technology in a specific middle school; therefore, the result cannot be generalized to include other schools. Besides, other schools may decide to implement the program in different ways with regard to the number of hours students engage with the program, who facilitate the program, schedule for implementation and the number of students that implement the program in a class period.

Sample size for the teacher and administrative interview is relatively small because of the population of the school consequently; the study is limited to the responses of this small sample size. The inclusion of other form of data collection such as students' standardized test scores and ST Math pretest and posttest data enabled triangulation of the data, Also, the data is restricted to student performance in mathematics and does not involve other subjects or the school climate.

To enhance the trustworthiness of the research, the use of triangulation of the data from two sources (interviews and reported scores), member checking of the interview transcripts and follow up interviews contributed in boosting the trustworthiness of the research. The alignment with the literature review also supported the interpretation of the findings of the study.

Recommendations

This study examined the advantages and challenges of implementing ST Math in one location with a small sample of participants. Future research, therefore, can aim at studying more than one setting with a large number of students, teachers, and administrators. Besides, the perception of teachers and administrators regarding the ST Math program was gathered in this research. Future studies can focus on getting the opinion of the students. Since the students are directly engaging with the program, their views will contribute to the better triangulation of the interview data. The interview questions for this research are generated using the research questions. Future studies can also be founded on the use of the theoretical framework to design the research question. Finally, looking at the result from the ST Math pretest and posttest, and the state standardized test score result, students, have growth from when they took the pretest to when they completed the posttest. While on the other hand, the state standardized test shows no major growth until five years later. Research is needed to find out why the differences. In other words, research is necessary to examine the relationship between the ST Math pretest, posttest and the standardized testing.

Implications

There are numbers of implications that came out of this study. Findings from this research shows that ST math is a research-based technology program that enhances students' mathematics skills and proficiency; therefore, implementation of ST Math as an intervention program in Midland Middle School will bring about a change in students learning and mastery of mathematics skills. In other words, educators can use ST Math to shift the mathematics curriculum to address the needs of some of the middle-school students' mathematics learning and proficiency. The three theories applied in this study contribute in enhancing students' learning in a technological driven society. Equally, several suggestions were made by the participants that can enhance the use of the program in the classroom. Below are the recommendations:

1. When students, teachers and administrators actively take part in minimizing the challenges involved in the implementation of the ST Math program, students' mathematics proficiency will improve.
2. The class size should be reduced to smaller groups to enable the facilitator assist individual students and if retaining larger size of class, an aid should be assigned to the ST Math computer lab to support the facilitator.
3. Students should be encouraged to use a headphone to block out classroom distractions.
4. It is more beneficial for the class time to be broken down to a maximum of 30 minutes since it is difficult for some students to stay on task for long.
5. Different incentives that will motivate students to continue to participate in the program should be put in place.

Conclusion

This qualitative study provides a deeper understanding and perception of the teachers and administrators perception regarding the implementation of the ST Math program in Midland Middle School. Understanding teachers and administrators' perception is crucial because it can inform instructional practices and promote effective technology use that enhances students' learning in a manner that will promote positive social change. Teachers and administrators ascertained that the ST Math program is advantageous in the learning, teaching and mastering of the mathematics skills. ST Math program; therefore, promote social change by enlightening educators, stakeholders, policy makers, and educational decision makers of the necessity of understanding teachers’ perceptions of the ST Math program and ensuring the continuous use of the program throughout seventh and eighth grade to maximize its benefit in the middle school. Also, the outcome of the study may add to the body of literature where there has been a lack of research on the advantages and challenges of ST Math in middle school and could potentially produce several positive outcomes in the domain of curriculum, instruction, and assessment.

Further research involving multiple middle-school sites with a large number of teachers and students is needed to promote the ST Math program. Equally, there is the need to learn about students’ perspective as the engage with the program. The literature presented in this study point out that technology application such as ST Math contribute to enhancing and enriching schools and classroom that have implemented it. Vygotsky Activity theory, the 21st century skills theory and Mayer cognitive theory of multimedia learning have served as a course of action for the implementation of efficient approaches to engaging teachers and students in a technology driven instruction and learning. In conclusion, the finding of this research adds to the knowledge that research-based technology programs and application in the classroom promotes learning and mastering of mathematic skills and proficiency.

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Appendix A: Interview Protocol

Examining the implementation of Spatial-Temporal Math in Middle School

Time of Interview:

Date:

Place:

Interviewer:

Interviewee:

Position of Interviewee:

Description of the project and introduction:

Thank you for your willingness to participate in the interview part of my study. As mentioned previously, my study seeks to understand teachers and administrators' perceptions of the advantages and challenges of implementing ST Math, instructional program on middle school (seventh and eighth grade) students' learning and proficiency in mathematics. I will also descriptively examine what students' test results indicate about the overall changes in students' test scores when continuous implementation of the program is used in seventh and eighth grade compared to prior to its use. Today's interview will last at least 45 minutes. I will be asking you about your perceptions of the advantages and challenges of implementing the program. As indicated in the consent form, do I have your authorization ___Yes ___No to audio record our dialogue? If your answer is yes: Thank you! If at any point you are not comfortable with me recording, please let me know I will turn it off. If your answer is no, I will take notes instead. Do you have any questions before we begin the interview? Please feel free to ask questions at any point during the interview I would be more than happy to answer them.

Questions for mathematics teachers

1. What do you think about the ST Math program and the advantages of implementing it in the middle school?
2. How does ST Math as a multimedia 21st century skill technology program contributes to students' mathematics skills and proficiency?
3. How did the ST Math program affect students' attitude towards math?
4. In your view, what are the challenges students face using ST Math and what can be done to avert these challenges?
5. What are the challenges teachers face implementing ST Math and what can be done to avert these challenges?
6. Do you have suggestions on how best to implement the program in the school?
7. What is evident in students' mathematics test achievement as the use the ST Math program? What do you attribute to this success or lack of success?
8. How do you think the continuation of the implementation of ST Math program in the school has reflected on students' mathematics proficiency?

Questions for the administrator and CIP facilitator

1. What do you think about the ST Math program and the advantages of implementing it in the middle school?
2. What are the advantages of implementing ST Math program?

3. What is evident in students' mathematics test achievement as the use the ST Math program? What do you attribute to this success or lack of success?
4. How do you think the continuation of the implementation of ST Math program in the school has reflected on students' mathematics proficiency?
5. In your view, what are the challenges students face using ST Math?
6. What are the challenges teachers face implementing ST Math
7. What do you think can be done to avert these challenges?
8. Do you have suggestions on how best to implement the program in the school?

(Thank you for your participation in this interview. Your responses to these questions will remain confidential).

Appendix B: Mathematics Proficiency Level Prior to (2014 and 2015) and After Implementation (2016–2018), Percentages

School Years	2013/2014	2014/2015	2015/2016	2016/2017	2017/2018
7th grade					
8th grade					
Number of students					

ST Math Pretest and Posttest Scores

	2017/2018		2018/2019	
Grades	Seventh	Eighth	Seventh	Eighth
Number of students				
Pre-test (Mean)				
Post-test (Mean)				