The Impact of Science, Technology, Engineering, and Mathematics (STEM) Integration on Third, Fourth, and Fifth Graders' Mathematics and Science Achievement

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Abstract

The purpose of this explanatory sequential mixed-methods study was to assess the impact of the STEM integration program on third through fifth grade students' achievement scores in mathematics and science in an urban northeastern Georgia school district. In Phase 1, a quantitative research design was used to examine and compare student achievement among third, fourth, and fifth grade students. Statistical *t* tests were performed to determine if there were any significant differences between the students' achievement data who were taught with the integrated STEM program (i.e., experimental group) and their counterparts who were taught with a traditional mathematics and science curriculum (i.e., comparison / control group).

Phase two encompassed the employment of qualitative research measures to provide clear and logical explanations regarding the instructional practices utilized to teach mathematics and science curriculum content to third, fourth, and fifth grade students. The qualitative research design included online questionnaires and interviews administered to four focus groups that constituted instructional liaisons and teachers from STEM and non-STEM elementary schools. Descriptive statistical data collected during the qualitative component of the research provided comprehensive and graphic rationales and justifications for the outcomes and deductions established during this investigation. There was one overarching research question and six hypotheses that were tested to determine the impact of the STEM integration program on third through fifth grade students' achievement in mathematics and science. This study concluded with the findings, implications for practice, and recommendations for further research.

Dedication

To my mom and dad, Maenolia and Lawrence McGraw, for always encouraging me to keep striving and to never give up on my dreams.

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First giving honor to God, who is the head and Savior of my life. It is because of God's grace, mercy, and favor that I have made it this far. I am eternally blessed that God has granted me the guidance and strength to make it to the end. This has been a long and arduous journey. It is only befitting that I thank those who have been on this road with me. I would like to thank each member of my dissertation committee: Drs. Siegrist, Downey, Pate and Leech. Without the support from each of you this opportunity would not be a reality. To my children, Leon, Rashaad, Lavantai and LeAndre, who have helped me along the way, I am eternally grateful for your support in my life. To the backbone that has kept my house, life and mind running, my husband, Leon. There will never be enough words to say how much I appreciate all that you do to help me. Not just as I have worked to get over this hurdle, but as we have worked to make it over many hurdles together. For better or worse, in sickness and in health…you have taken those words to heart and have been a backbone that has given me strength even when I didn't have it for myself. I love you and I can never thank you enough. Terri Bell, you have been an extra pair of eyes, an editor, and a listening ear. I appreciate you taking the time out to listen and to help me put my thoughts to the page. Finally, to my friends, who have pushed me when I wanted to quit, listened to me when I wanted to cry, argued with me when I refused to go on, and stood beside me throughout this process: Terri Bell, Melissa D. Walker, and Tiffany Hogan I appreciate each of you for being there throughout this process.

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CHAPTER I

Introduction

The educational process for the youth of today is much different than the educational process students experienced prior to the turn of the century (James, 2014; Mohr-Schroeder et al., 2018; Quellmalz et al., 2013; Thomas, 2013). Researchers have found America continues to lag other countries academically in science, technology, engineering, and mathematics (Akyüz, 2014; Bybee & Stage, 2005; National Center for Education Statistics, 2015; Wilkins & Jones, 2009). It is important that educators respond to the needs of the students and a modern society (James, 2014).

Local, state and federal education reform measures have been designed to address mathematics and science deficits in kindergarten through twelfth grade (Georgia Department of Education, 2015a; No Child Left Behind (NCLB) Act, 2002). The No Child Left Behind Act of 2001 (NCLB) was a major initiative introduced and implemented as reformation platform and amendment to the Elementary and Secondary Education Act of 1965 (NCLB, 2002). The Bush Administration implemented the No Child Left Behind initiative to address the imbalance observed in the educational achievement of students across the nation (Dillon & Rotherham, 2007; Mohr-Schroeder, Bush, & Jackson, 2018).

Paige (2006) indicated that the NCLB Act required increased accountability for schools and teachers and was designed to ensure a decrease in the student achievement gap across the United States. The legal parameters of the NCLB legislation dictated that schools be held accountable through the administration of annual testing that assessed student performance and improvement (Paige, 2006). Subsequently, standardized testing has become a primary component for measuring the performance level of schools. Despite specific efforts that have been made, the student performance gap on standardized assessments has significantly increased across the United States (Mahoney 2010; Weinstein, 2010).

Assessment data indicates student achievement in the mathematics and science areas continues to be a challenge for most school districts across the United States (Dillion & Rotherham, 2007).

In March 2010, President Obama introduced an educational reform initiative as an amendment to the No Child Left Behind Act of 2001 (Weinstein, 2010). Specific revisions in the No Child Left Behind Act included the provision of funds for states to implement an even broader range of assessments to evaluate advanced academic skills. Students' abilities to conduct research, use technology, engage in scientific investigations, solve problems, and communicate effectively were some of the academic skills included in President Obama's initiative (Mahoney, 2010). President Obama's educational reform platform lessened the stringent accountability penalties for states by focusing more on student improvement as improvement measures would provide a way to assess all children more appropriately, including English Language Learners, minorities, and special needs students. School systems were expected to be re-designed so measures beyond reading and mathematics tests would be used (Weinstein, 2010).

Bybee and Stage (2005) and Wilkins and Jones (2009) agreed that the achievement deficits in mathematics and science in the United States are due to the schools' emphasis on the acquisition of knowledge at the expense of problem solving and application. Moreover, the researchers suggested that disparities in mathematics and science achievement may be addressed by developing students' critical thinking skills and mathematical knowledge (Bybee & Stage, 2005; Wilkins & Jones, 2009). Gagnon and Miccioni (2007) supported the argument that the problem with poor performance in mathematics is not computation but result from a failure to be exposed to advanced mathematics concepts and challenging material. Research-based instructional practices and programs must be considered for students to gain the skills needed to succeed in the 21st century (Georgia Department of Education, 2015b).The National Science Board (2010) proposed that an initiative integrating science technology, engineering, and mathematics (STEM) into the school-wide curriculum was a viable solution to help students improve their performance in science and mathematics. Researchers (Akyüz, 2014; James, 2014; Meyrick, 2011; Quellmalz, et al., 2013) maintained there was a critical need for a directional change in the instructional techniques that had been employed throughout the United States prior to 2013. The STEM program in elementary schools came to prominence in November 2009 when President Obama made changes to the No Child Left Behind Act with the introduction of the Educate to Innovate Campaign, as referenced by President Obama during his remarks during the White House Annual Science Fair on April 25, 2013 (White House, 2013). President Obama helped to create "*Change the Equation,* a new non-profit organization with a full-time staff to improve the quality of STEM education in the United States" (White House, 2013, para. 7). The President also called for 100,000 teachers to be prepared to be effective STEM educators by 2023 (Educate to Innovate –White House, 2013).

Integrated STEM programs in elementary schools have emerged since former President Obama's initiative was implemented. DeJarnette (2012) stressed the need for additional integrated STEM programs in elementary schools. However, a review of the literature found limited research that assesses the effectiveness of the programs.

Statement of the Problem

The problem addressed in this study is the lack of information about the impact of the STEM integration program on third, fourth and fifth grade students' achievement in mathematics and science. A persistent precept for educational reform in school districts across the United States has been the continued decline in student achievement and performance in the fields of mathematics and science from elementary through high schools. Integrating STEM programs into those areas of study in elementary schools has been proposed as needed reform in elementary school curriculum (Hamos et al., 2009; Kay, 2009; Reeves, 2011; Shaffer, 2009; Wilkins & Jones, 2009). As a current high school administrator who has served on all educational levels in the public school system (elementary, middle, and high), I have experienced first-hand what happens to students who do not have a solid mathematics and science foundation established during their formative years. The failure to develop and master mathematics and science content essential skills during the early educational years can produce negative consequences and problems for students as they matriculate through upper grade levels.

Purpose of the Study

The purpose of this study was to examine the impact of a STEM integration program on third, fourth and fifth grade students' scores in mathematics and science in an urban northeastern Georgia school district. This study investigated if significant differences exist between the students' achievement scores (dependent variable) who were taught with the integrated STEM curriculum (independent variable) and their counterparts who were taught in a traditional (non-STEM) mathematics and science curriculum (independent variable). The result from the analysis provides information about the impact the STEM integration curriculum had on third, fourth and fifth grade students' achievement scores in mathematics and science in comparison to students who had traditional mathematics and science instruction. The findings from this study will add to the knowledge base about whether integrating STEM programs in third, fourth and fifth grade science and mathematics impacts standardized achievement test performance more than a traditional curriculum.

This explanatory sequential mixed method study investigated the impact that integrating a STEM program in science and mathematics classes has had on elementary school students' scores on End-of-Grade standardized tests in a state in the Southeastern region of the United States. The primary focus of this research was to explore academic achievement outcomes for approximately 3,600 students in third, fourth and fifth grades for the 2015-2016 academic year. One overarching research question and six hypotheses guided the research.

Research Question and Hypotheses

The following overarching research question guided this explanatory sequential mixed method study: What effect, if any, did the integration of a STEM program have on third, fourth, and fifth grade students' mathematics and science achievement scores in comparison to third, fourth and fifth grade students taught with the traditional mathematics and science curriculum? Questionnaires and interviews provided the consistency of historical data through triangulation. The following null hypotheses were tested:

$H1_0$: There is no significant difference between the mathematics achievement scores of third grade students in a mathematics class with an integrated STEM program and third grade students in a traditional mathematics class.

$H2_0$: There is no significant difference between the mathematics achievement scores of fourth grade students in a mathematics class with an integrated STEM program and fourth grade students in a traditional mathematics class.

$H3_0$: There is no significant difference between the mathematics achievement scores of fifth grade students in a mathematics class with an integrated STEM program and fifth grade students in a traditional mathematics class.

$H4_0$: There is no significant difference between the science achievement scores of third grade students in a science class with an integrated STEM program and third grade students in a traditional science class.

$H5_0$: There is no significant difference between the science achievement scores of fourth grade students in a science class with an integrated STEM program and fourth grade students in a traditional science class.

$H6_0$: There is no significant difference between the science achievement scores of fifth grade students in a science class with an integrated STEM program and fifth grade students in a traditional science class.

Background, Context and Premise for the Study

This study evolved out of the concern expressed in the research literature about the academic achievement level of students in the United States that remained stagnant over the past 20 years (Akyüz, 2014; Brown et al., 2011; James, 2014; Kay, 2009; Quellmalz et al., 2013). In 2018, 79 countries administered the PISA exam to more than 600,000 students in public and private schools. Thirty countries' math scores were higher than math scores from the United States and the latest scores indicated that when isolating the sixty- four countries that administered the test in 2015 and 2018, U.S. students ranked 11th in science (NCES, 2021). U.S. students' math scores have remained steady since 2003. Their science scores have been about the same since 2006 (NCES, 2021). Educators have proposed that implementation of one or more integrated STEM programs at the elementary school level could make a significant positive difference in student achievement scores (Kay, 2009; Reeves, 2011; Wilkins & Jones, 2009).

The primary grades have been identified as critical for student learning because that is where students' educational foundations are formed (Shaffer, 2009). The potential that STEM integration programs in elementary school mathematics and science classes have been expected to be stronger than interventions used at later stages of development (Hamos et al., 2009; Shaffer, 2009). More research was suggested to investigate whether integrated STEM programs impacted elementary student achievement in mathematics and science (Hamos et al., 2009; Kay, 2009; Shaffer, 2009; Reeves, 2011; Wilkins & Jones, 2009).

The conceptual framework for the study is grounded in the type of curriculum model employed for third, fourth and fifth grade content areas of mathematics and science (STEM or traditional). STEM integration programs use a variety of instructional techniques to meet the needs of diverse groups of students including, but not limited to; differentiated instruction, direct instruction, inquiry-based instruction, project and problem-based instruction, and technology enhanced instruction (Clark, 2014; Reeves, 2011; Wells, 2013). Research has shown that student outcomes improved when students were actively engaged in an integrated learning process (Akyuz, 2014; Clark, 2014).

The integration of a STEM focused elementary level program in the targeted district in this study embraced a cross-curricular, critical thinking approach that incorporates science, technology, engineering and mathematics (STEM) into all content areas through engaged learning that provides a hands-on experience (Georgia Department of Education, 2010; Georgia Department of Education, 2016; Sanders, 2009; Wells, 2013). The Georgia Department of Education adopted the Virginia Tech integrated STEM education program, also known as the Purposeful Design and Inquiry (PD&I) model, as the STEM model of choice for school districts that attained state STEM certification. The PD&I model emphasizes project-based and problem-based teaching and learning (Wells, 2013).

Sanders (2009) and Wells (2013) refer to the PD&I model as the amalgamation of technological design, scientific inquiry and student engagement that merged engineering problem-solving and project learning via an interactive environment. A major component of the PD&I model is a design challenge task that requires students to participate in problem-based learning. The problem-based learning activities have been embedded in scientific inquiry practices, which have been linked to mathematical applications that fostered engineered resolutions for real-world scenarios (Carter, 2013; Sanders, 2009; Wells, 2013). Student engagement and student collaboration immersed with teaching practices that incorporate engineering design challenges that require students to integrate science and mathematics content standards in a student-centered environment for real-world application represents the foundational precepts for STEM education at the elementary level (Sanders, 2009; Wells, 2013).

Significance of the Study

Patterns from data reported in the research literature show the critical need for a directional change (a different way of teaching) in the instructional techniques that were employed to improve student achievement in the content areas of mathematics and science (Akyüz, 2014; Brown, et al, 2011; James, 2014; Kay, 2009; Quellmalz et al., 2013). Directional change teaches problem solving and analytical skills, as opposed to the traditional instructional technique, where students are given step-by-step directions to achieve an answer. Collaborative efforts are essential for the success of the students in the 21st century (James, 2014; Louck-Horsley & Matsumoto, 2010). The role and impact that an integrated STEM program curriculum has on academic achievement in science and mathematics for all students (i.e., elementary, middle and high) are limitless (James, 2014). This study focused on the mathematics and science performance of elementary school students, specifically third, fourth and fifth graders. Research shows that intervention during this stage of the students' educational experiences would be more beneficial than interventions introduced at a later stage of development. STEM integration instruction may be the key to increasing students' mastery of concepts and academic skills, as well as, improving the quality of teaching and learning (James, 2014).

Additionally, results from this research could help district level personnel as well as administrators at the eight schools (i.e., experimental and comparison groups) make evidence-based decisions. This study provided school staff the opportunity to critically examine the variables that influence student achievement in mathematics and science within their respective schools, as well as to make comparisons between the instructional methods used. Additionally, the findings could contribute to a database that shows research-supported strategies to improve the educational status of students in the United States. Moreover, the results of the study may be used to influence elementary school administrators and teachers to make effective decisions and implement strategic changes in the cultural and instructional practices to decrease the achievement gap.

Limitations and Assumptions

Limitations for this study have been identified. The sample for this study was chosen from schools with similar demographic profiles such as: (a) number of students enrolled, (b) gender, (c) racial/ethnic demographics and (d) free and reduced Lunch status (e.g., socioeconomic background of the student population). Generalizations inferred from this study will require readers and researchers to examine student demographics, curriculum similarities, and differences to assess whether the results might be applicable to other schools. Results can only be generalized to participants/schools that share similar characteristics to those in the proposed study.

Participants in this study were enrolled in a large school district in Georgia; therefore, it is the expectation of the researcher that a diverse sample of students and demographics was obtained. This study did not address all plausible alternative explanations for differences in mathematics and science student achievement measurements of an integrated STEM program in elementary schools as compared with traditional elementary schools (e.g., levels of intelligence, achievement motivation, parental involvement, socialization of boys toward the sciences and mathematics, and girls' attitudes toward the social sciences, humanities, or helping careers).

As a former teacher, it is the experience of the researcher that teachers do not always teach every part of a curriculum in the exact same manner, therefore an additional limitation in this study is the fidelity of implementation of the curriculum by the teachers at the selected schools. The variances in the implementation of the curriculum are based on teachers' passions, prior trainings, knowledge and background to the STEM culture and curriculum. These variances may not have been expressed to the researcher or the STEM coordinator because they were not pre-existing qualifications for the positions. The Georgia Department of Education (2015b) sets the standards for the STEM integration program and traditional curriculum implementation. The Georgia Department of Education also sets expectations for how the programs are implemented. However, oversight and evaluation of both programs are at the local level, except for a 5-year on-site review of the STEM integration program by personnel from the Georgia Department of Education STEM department.

Definition of Terms

The following terms are essential to the study as they provide a basic and uniform understanding of concepts that are presented in this study.

Achievement gap. Achievement gap is a term used to describe the persistent disparity in academic performance between groups of students belonging to different racial and economic groups enrolled in Georgia schools (Georgia Department of Education, 2016).

Achievement Level Descriptors (ALD*).* Achievement Level Descriptors were developed by educators in Georgia. The ALD provided descriptions of students' command and mastery of skills and knowledge they must evidence based on the content standards for the state. There are four ALD: (a) beginning learner, (b) developing learner, (c) proficient learner, and (d) distinguished learner.

Engineering design process (EDP). The EDP is a procedure for solving real-life challenges that involves five steps: ask, imagine, plan, create, and improve (Pahl & Beitz, 1988). STEM classes are founded in the EDP, which allows for student academic growth over time as problems are solved and procedures are improved.

Free and Reduced Lunch. Household income determines whether students receive free or reduced lunch (USDOE, 2012). Students receive free and reduced lunch if parents are recipients of food stamps or assistance for needy families or are recipients in the food distribution programs on Indian Reservations. For a child to receive free meals household income must fall below 130% of the federal poverty level. For reduced price meals household income must be between 130% and 185% of the federal income level (USDOE, 2012).

Georgia Criterion-Referenced Competency Test (CRCT*).* The CRCT was designed to measure students' proficiency on the Georgia Performance Standards (Georgia Department of Education, 2010). The standards specify the skills, knowledge, and academic competencies that students are to be able to perform in each subject area. The assessment specifies students' strength and weaknesses and may be used as a diagnostic tool in addressing students' competencies or lack thereof (Georgia Department of Education, 2010).

Georgia Milestone Assessment System (GMAS*).* The Georgia Milestone Assessment System (GMAS) was adopted February 19, 2015, to replace the use of the CRCT throughout the state of Georgia. According to the Georgia Department of Education, the GMAS is used to assess the degree students learned the knowledge and skills as required by the content standards for the state in language arts (LA), Mathematics, Science, and social studies (Georgia Department of Education, 2015a). The GMAS is designed to give information to all the stakeholders of the school information about the students' strengths and weaknesses, for example their readiness for the next grade level or career or college.

Helping career. Any career that has historically been identified as a female only career, such as secretary, nurse's aide, teacher's aide, etc.

Highly qualified. Highly qualified teachers must have the following credentials: a bachelor's degree, full state certification or licensure, and proof that they are successful in teaching the subjects they teach (Georgia Department of Education, 2016)**.**

Integrated STEM. Integrated STEM is "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics in one class, unit, or lesson that is based on connections between the subjects and real-world problems" (Moore et al., 2014).

Performance level. Performance level refers to a range of scores that reflect student achievement in a subject based on performance level descriptors. The GMAS used since Spring 2015 has four performance levels which are described as Achievement Level Descriptors: (a) beginning learner, (b) developing learner, (c) proficient learner, and (d) distinguished learner (Georgia Department of Education, 2015a).

Science, technology, engineering, and mathematics (STEM). The STEM instructional program requires content to be integrated so that students can experience the relevancy of the information being taught. (Lam, Doverspike, Zhao, Zhe, & Menzemer, 2008). STEM "is an interdisciplinary approach learning where rigorous academic concepts are couples with real-world lessons…that make connections between school, community, work and the development of STEM literacy and with it the ability to compete in the new economy" (Tsupros, Kohler, & Hallinen, 2009).

Traditional courses. Traditional courses are those taught using explicit instruction in only one content area at time (James, 2014). As explained by Lam et al. (2008), teachers are inclined to believe the content they teach is to be taught in isolation from other content areas. The researchers concluded that teachers in traditional classes generally plan lessons in a more isolated manner than in STEM classes.

CHAPTER II

Review of Literature

This chapter presents the results from the review of literature. First the importance of strategic, systematic changes in the instructional format is discussed. Children in the school systems today are different than children of yesterday (Shaffer, 2009). The current demands placed on teachers and students make it clear that help is needed (Georgia Department of Education, 2016; USDOE, 2012; Zollman, Tahernezhadi, & Billman, 2012). Research related to the use of integrated STEM programs and academic achievement is reviewed. Next, the traditional curriculum is presented to understand the advantages and disadvantages of the two instructional paradigms. A review of literature related to the theoretical framework used to support the work developed for this study is described. This chapter also includes a discussion of the impact of teachers' expectations and levels of self-efficacy on the academic performance of the students. The last section of this chapter provides a summary of the information presented.

A Need for Change

The academic achievement gap has continued to increase despite the efforts the federal government and some schools that have expended to improve the educational status for all students in the United States (Georgia Department of Education, 2016; James, 2014; USDOE, 2012). James (2014) described how some elementary schools continued to have a decline in the academic performance of students in grades three through five. Educators in school districts across the United States have been searching for ways to better educate their students (Brown, Readon & Merrill, 2011; Clark, 2014; Loucks-Horsley & Matsumoto, 2010). In most instances, local, state, and federal authorities have demanded change (Georgia Department of Education, 2015; Mosely, 2015; NCLB, 2002; Thomas, 2014).

The consensus among researchers was that there continued to be a decline in the academic performance of students in the United States as early as elementary school that became exacerbated as the students grew and developed if no intervention was provided (James, 2014; Thomas, 2014). James (2014) reported a progressive decline in Mathematics achievement at the elementary and middle school levels. He stated that there was a critical need for research to identify educational strategies and techniques that would make mathematics and science more relevant to elementary and middle grade students. James's conclusions were like those made by Sallee (2005). Sallee's argument validated the need for change in the instructional practices of mathematics and science teachers across the nation. The purpose of implementing the instructional changes would be to enhance the quality of life for the next generation through college and career readiness preparation (USDOE, 2012).

In a study by Zollman et al. (2012) the researchers concluded educators should accept "we are now in the STEM generation" (p. 12). The researchers found that numerous reports and programs have been commissioned in the United States regarding STEM education. The programs and reports had three parallel concerns:

> (a) the future need for more scientists, technicians, engineers, and mathematicians (the supply pipeline); (b) the necessity for more innovative workers (a knowledgeable population) trained in science, technology, engineering, and mathematics; and (c) recommendations for what schools should do to solve the shortage. (p. 123)

They also proposed that what happened in the classroom depended on the quality of the teacher. The greatest influence on student learning comes from the teacher. Therefore, it has become more critical for schools to ensure that teachers have access to professional development opportunities so they can continue to motivate, nurture students' cognitive abilities, and provide content knowledge (Zollman et al., 2012). The next section reviews research on an instructional paradigm that is expected to help teachers and students attain their professional and educational goals.

STEM Integration Program and Academic Achievement

One example that shows the potential to enhance student achievement is the STEM model, which integrates science, technology, engineering, and mathematics into the mathematics and science curriculum (Akyüz, 201; James, 2014; Meyrick, 2011). Meyrick (2011) explained that the development of a STEM curriculum in the education system may provide the crucial framework to support students as they master content that was important for their learning. Santoli, Sachs, Romey and McClurg (2008) provided additional research support for integrating STEM programs into the instructional curriculum. The authors concluded that for educators to effectively assist all students in reaching their full potential, it was essential that teachers were provided access to the best professional development, quality resources, and instructional support to increase their commitment to the success of all students. It was believed that students and teachers who were afforded an opportunity to incorporate integrated STEM instruction at the elementary, middle, and high school levels would significantly increase students' performance and growth on state standardized tests (Mosley, 2015; Robelen, 2011; Santoli et al., 2008; Thomas, 2014; Tice, 1999; Zollman et al., 2012).

Robelen (2011) determined that a STEM curriculum could increase students' ability to comprehend and master mathematics' skills at a faster rate. Robelen also found that the integrated STEM approach enhanced critical thinking and problem-solving skills through employment of real-world and authentic learning experiences. The integrated STEM approach also incorporated essential mathematical concepts into activities that were engaging, interactive, and innovative. Davis (2011) explained that the integrated STEM programs approach had an important advantage for utilizing technology with mathematics. Part of this advantage was exhibited in the students' confidence with investigation and analyzation. Achievement level increased because of students' frequent use of digital and electronic communication devices to identify different reasons why the integrated STEM program approach is expected to succeed. For example, Bright (2010) suggested that a positive aspect for the implementation of a STEM program was that it centered on hands-on activities that encouraged the use of manipulative devices and collaborative and cooperative group work. Findings from Bright's study indicated that the identified factors positively impacted students' achievement. Thomas (2014) found similar results as did Patel (2010). Thomas considered the teachers' perceptions about the use of the integrated STEM program. Overall, he found that teachers had positive attitudes about STEM education. Patterns from the data showed that (a) teachers new to the field were more positive about STEM than were veteran teachers, (b) general education teachers were more positive than teachers in the special education program, and (c) teachers who taught the higher-grade levels were more positive than teachers in the primary grades. Patel (2010) also supported the STEM integration vision. Patel concluded that complex concepts in mathematics, science, technology, and engineering were best taught through hands-on learning that was interactive and engaging.

Brown et al. (2011) believed that an integrated STEM program approach provided a more stimulating learning environment for the students. Assessments revealed the use of STEM integration resulted in an increase in problem-solving, critical thinking, and analytical thinking skills. Brown et al. (2011) also presented a dialogue on the importance of the positive outcomes and real-world connections that STEM participation afforded students.

Swift and Watkins (2004) affirmed that the optimal impact of a STEM approach could only be attained through the practice of effective, engaging, and highly qualified science and mathematics instructors at the elementary school level. However, according to Swift and Watkins, the pool of candidates of mathematics and science highly qualified elementary teachers in the United States had been very small, which directly impacted the quality of the instruction being taught in the classroom. Wilkins (2010) acknowledged that elementary teachers did not possess a degree or a teaching certificate in the areas of science or mathematics and frequently felt inadequate and unprepared in their ability to effectively teach mathematics and science standards. Wilkins (2010) indicated that elementary teachers experienced mathematics anxiety and feelings of low mathematical efficacy due to a lack of content specialization in the critical need areas of mathematics and science. Under these conditions, it would not be predicted that the students would do well if their teachers believed they were not competent in the subject.

Kajander (2007) identified another way teachers could inhibit learning. While elementary instructors possessed the skills required to compute correct answers to elementary mathematical problems, the teachers lacked the ability to clearly justify and expound on the techniques that were utilized to solve mathematical performance tasks.

Based on the prevailing sentiment from the current body of research on the implementation of an integrated STEM mathematics and science instructional program at the elementary school level, it seemed appropriate to expand the use of integrated STEM approaches in American schools. Results suggested that it would be worth the efforts and resources needed to implement STEM approaches in the schools (Sahin et al., 2014; Thomas, 2014). The data that were collected indicated a strong aspiration to discover, develop, and implement an instructional tool that would re-focus and enhance the practice of teaching and learning in the fields of mathematics and science in the United States. As explained previously, the concept of integrating mathematics, science, engineering, and technology afforded students an opportunity to take advantage of a more engaging, interactive, and innovative education that would prepare them to be highly qualified college and career ready candidates upon graduating from high school (Thomas, 2013).

Finally, it should be noted that the use of integrated STEM approaches in the classroom would present the schools with many advantages and opportunities, as well as challenges (Dance et al., 2013; Nadelson et al., 2013). In this context, the advantages have been described in detail. The challenges that have been identified with the use of integrated STEM approaches revolved around (a) availability of appropriate resources, (b) preparedness of the teachers to instruct using integrated STEM approaches, and (c) an apparent focus on English/Language Arts and Mathematics learning standards (Nadelson et al., 2013). Educators must plan to be successful when using an integrated STEM approach. When compared to the traditional curriculum for elementary school students in the subject areas of mathematics and science, the traditional curriculum has been viewed as the dinosaur and the integrated STEM curriculum as a reflection of the 21st century (Bruce-Davis et al., 2014; Mosley, 2015; Nadelson et al., 2013; Ricks, 2012).

Traditional Curriculum

The traditional curriculum has been described as instruction limited to one subject area at a time and compartmentalized information (Mosely, 2015). McMahon (2015) described the traditional curriculum as one that adhered to conventional practices and guidelines. She agreed with Mosley's (2015) assessment that the focus of the traditional curriculum was narrow. A discussion of the traditional curriculum could be done in terms of the (a) specific courses and the order that the courses must be taken to earn a diploma or degree and (b) actual content covered in the class. Courses that students normally take with the traditional curriculum include language arts, history, mathematics, science, and courses in the social sciences (e.g., psychology, sociology, political science). Courses are presented in a progressive order whereby each level is more challenging than the previous level. Thus, students are expected to build and use their skills as they proceed through the curriculum (Beck, 2009).

The traditional curriculum has historically received criticism. In recent times it has been scrutinized more frequently and sometimes was not selected as a method that consistently resulted in high academic achievement (Beck, 2009). The traditional curriculum often resulted in rote learning and memorization. It has also been shown to support testing. As Beck explained, the traditional curriculum was used to "transmit to a next generation those skills, facts, and standards of moral and social conduct that adults consider to be necessary for material and social success" (p. 3). The use of the traditional curriculum meant that all the traditional (i.e., conventional) strategies were involved such as traditional mathematics, direct instruction, rote learning, grades, lectures, tracking, and standard algorithms. For example, in traditional mathematics students receive direct instruction, rote learning is expected, grades are given, lectures are presented, students are tracked, and standard algorithms are the rule (Beck, 2009).

The opposite of the traditional curriculum would be the approaches that have been described as progressive, integrative, or holistic (Beck, 2009). In the traditional curriculum, science would be taught as fact-based, concrete knowledge, and specific vocabulary words would be provided to the students by the teacher or assigned in the textbook (Beck, 2009). Teachers expected students to memorize information and follow a recipe-type plan to conduct an experiment that would produce expected results (Mosley, 2015). In contrast, teachers using an integrated or inquiry-based curriculum might ask the students to design and conduct an experiment that would demonstrate a specific concept, such as how the earth orbits around the sun. The inquiry-based approach would have the student learn by doing; hence, knowing the information rather than merely memorizing facts (Beck, 2009; Nadelson et al., 2013).

Theoretical Framework

The core focus of this study was centered around how the integrated STEM program influences student outcomes in mathematics and science. The independent variable is the type of instructional technique used (i.e., integrated STEM program versus the traditional classroom). The dependent variable was third, fourth, and fifth grade students' performance on the Georgia Milestones Assessment System.

The instructional approach reflected in the integrated STEM programs are expected to have a positive influence on the performance of students in the subject areas of mathematics and science. First, integrated STEM programs make use of assessments, utilize different instructional techniques, and are a multidisciplinary approach (Nadelson et al., 2013). Robinson et al. (2014) explained that there was no one best method to teach students. Some of the instructional practices that have been used in classrooms following an integrated STEM program include assessments, differentiated instruction, direct instruction, inquiry-based instruction, and technology enhanced instruction (Mosley, 2015). Assessments are done to collect information about the effectiveness of the teachers as well as the students' academic achievement (Mosley, 2015).

Mosley (2015) explained that there has been a long-standing debate about which instructional practices were likely to have a positive influence on student achievement, particularly in the STEM areas. According to Mosely, the debate about the instructional practices centered on which one of the two methods was best to teach mathematics -- direct instruction or inquiry-based instruction. Whereas direct instruction meant that students were drilled and engaged in practicing the material, instructed to follow procedural tasks, and memorize facts, inquiry-based instruction emphasized active learning (Mosley, 2015). Inquiry-based learning is not viewed as passive, and students are actively engaged in the learning process. This practice has also been referred to as the constructionist approach (Zain, Rasidi & Abidin, 2012). Shirvani (2009) found that a teacher that used inquiry-based instruction was one who helped students "develop, reflect, evaluate, and modify their own conceptual frameworks as a result of learning" (p. 256).

Differentiated instruction means that the teacher responds to the needs and interests of the individual student (Mosley, 2015). Researchers have concluded that differentiated instruction was effective because teachers were able to motivate their students to learn and help the students make the information relevant to their own lives (Chapman & King, 2005; McTighe & Brown, 2005; Mosley, 2015). The self-referent theory was used to explain this effect. Self-referent theory predicts that students who make the material relevant to themselves or some aspect of their lives are more likely to remember, understand, and know the information than if they do not make the information relevant to themselves (Baron & Branscombe, 2012; Gutchess, Kensinger, Yoon, & Schacter, 2007; McTighe & Brown, 2005; Rogers, Kuiper, & Kirker, 1977; Sui & Zhu, 2005). Additionally, different learning styles are used, so students are able to utilize their preferred style as well as become familiar with other learning styles, which are expected to help them in the learning process (Mosley, 2015).

Integrated STEM programs involve a dynamic process that means that students are actively engaged in learning process. Support for this theory has been shown from the theories of

(a) active learning, (b) cognitive load, (c) discovery learning, and (d) inquiry-based learning (Moore et al., 2014). The first three are described in this section. The fourth one, inquiry-based learning, was introduced earlier. Active learning was described as an instructional strategy that worked because it engaged the student. Active learning enables students to work on meaningful activities and to engage in metacognition, for instance, think about what they are doing (Bean, 2011; Bonwell & Eison, 1991). Some of the activities that are used to actively engage the students are class games; collaborative learning groups; evaluation of class content; gallery walk; learning by teaching; problem solving, which is used to promote critical analysis and synthesis; reactions to videos on the topic being discussed in the class; reading; short written exercises; small group discussions; student debates; and think-pair-share (Bean, 2011; Bonwell & Eison, 1991). Active learning has consistently been shown to have a positive effect on academic achievement (Mosely, 2015; Robinson et al., 2014; Sahin et al., 2014).

Cognitive load is a term that was developed in the field of cognitive psychology (Sweller, 2008). Sweller is credited with the development of this theory. He stated that cognitive load was the sum of all of the mental effort used in working memory (i.e., short-term memory). Sweller was investigating what happens mentally when people engage in problem solving activities when he discovered cognitive load. Cognitive load has helped educators and researchers understand the cognitive structures that compose the learners' knowledge base. His argument was that the instructional strategy could be planned so that the cognitive load was reduced for learners.

There were three types of cognitive load identified by Sweller (2008). First, extraneous cognitive load described the way the information was presented to the learners. Second, germane cognitive load was used to describe the work involved in the creation of a schema (i.e., mental framework or storage of knowledge). Third, intrinsic cognitive load referred to the effort related to a specific topic. Research has shown that a heavy cognitive load had a negative effect on academic success and task completion.

Cognitive load can be measured (Granholm, Asarnow, Sarkin, & Dykes, 1996; Paas & Van Merrienboer, 1993). The task-invoked pupillary response has been reported as a sensitive and reliable measurement of cognitive load. It has been substantiated that the pupillary response related directly to an individual's short-term memory (Granholm et al., 1996; Paas & Van Merrienboer, 1993).

Discovery learning is an aspect of inquiry-based learning with the constructivist paradigm for learning (Mayer, 2004). Theoretical support for this learning theory evolved from the field of psychology (Mayer, 2004). Bruner (1961) has been given credit for the development of the discovery learning theory (Bruner, 1961; Mayer, 2004). The essence of this theory was clearly delineated by Bruner (1961), "Practice in discovering for oneself teaches one to acquire information in a way that makes that information more readily viable in problem solving (p. 26). This is an instructional strategy that embodies "Learning by doing" (Mayer, 2004, p. 14). Mayer stated that discovery learning occurred when the teacher gave the students information and resources so that they could discover the answers for themselves. Even though discovery learning has received support in the literature and shown to be a viable learning strategy for a large array of disciplines and diverse students, some researchers do not believe discovery learning to be effective technique (Kirschner, Sweller, & Clark, 2006).

The next section of this chapter includes a review of research that provides theoretical support for the use of the integrated STEM program to help students improve levels of achievement in mathematics and science. Regardless of the instructional strategy used in the classroom, research continues to allude to the notion that "the students are only as good as the effectiveness of the teacher would allow," (Mosley, 2015, p. 38). Barber and Mourshed (2007) stated, "The quality of an educational system cannot exceed the quality of its teachers. Top performing systems recruit their teachers from the top third of each cohort graduate from their school system" (p. 16).

State of Georgia STEM Program

The Georgia Department of Education adopted the Virginia Tech integrated STEM program as the STEM model of choice for school districts that attained state STEM certification, (National Research Council, 2014). This STEM model emphasizes project-based and problem-based teaching and learning and is also branded as the Purposeful Design and Inquiry (PD&I) Model. Sanders (2009) referred to PD&I Model as the amalgamation of technological design, scientific inquiry, student engagement merged engineering problem-solving, and project learning via an interactive environment. A premier component of the PD&I Model is a design challenge task that implores students to participate in problem-based learning embedded in scientific inquiry practices linked to mathematical application that fosters engineered resolutions for real-world scenarios (Carter, 2013; Sanders, 2009; Wells, 2013). Student engagement and student collaboration immersed in teaching practices that incorporate engineering design challenges that require students to integrate Science and mathematics content standards in a student-centered environment for real-world application represents the foundational precepts for STEM education at the elementary level (Sanders, 2009). A graphic of the Georgia STEM Integration Model is shown in Appendix A.

STEM education allows for more student collaboration, communication, critical thinking, problem solving interaction, and participation with innovative and interactive engineering design processes (National Research Council, 2014). The Georgia Department of Education (2015) has approved one curriculum for teachers at the elementary school level regarding the integration of STEM in grades three - five called Engineering is Elementary (EiE). In addition to this ground-breaking course of study EiE schools are encouraged to expose students to scientific-based resources such as science lab experience, school-wide garden education, and fish aquarium system instruction that correlates STEM concepts (ISTEM Standards) with traditional mathematics and science curriculum objectives for elementary level students (Georgia Department of Education, 2015; Cunningham, 2015; Cunningham & Berger, 2014).

Engineering is Elementary is a research-based first through fifth grade STEM curriculum that concentrates on students' knowledge of science and engineering design processes to create and develop solutions. The instructional protocol for EiE was constructed from 20 units that are designed to meet the ITEEA Standards for Technological Literacy and the Massachusetts' Science standards (Sargianis et al., 2012). EiE was generated to stimulate engineering and technological literacy and employs a research-based and criteria-centered program of study to traditional science-inquiry themes (Cunningham 2015; Cunningham & Kelly, 2015). The EiE curriculum was crafted to be a supplemental resource for the purpose of integrating STEM into the content areas of science and mathematics at the elementary level (Carter, 2013; Cunningham 2015; Cunningham & Berger, 2014: Cunningham & Kelly, 2015). The overall purpose of the EiE curriculum is to increase children's technological literacy; improve elementary educators' ability to teach engineering and technology; increase the number of schools in the United States that include engineering at the elementary level; conduct research and assessment to add to the current body of knowledge about engineering teaching and learning at the elementary level (Carter, 2013; Cunningham 2015; Cunningham & Berger, 2014; Cunningham & Kelly, 2015).

Another inventive STEM curriculum prototype sanctioned by the state of Georgia is the Small Fry to Go (SFtG) (Technology Solutions, 2004) prospectus, which initiated with the Family Technology Resource Centers. This STEM-infused informational resource center also makes available instructive learning and training opportunities for children and adults. The Small Fry to Go program is a research and standards-based curriculum that correlates state and national standards to STEM objectives.

Small Fry to Go was developed as a yearlong supplemental enhancement teaching resource for the content areas of math, Science, technology, and language arts that established school and community relationships and interactions between pre-K through eighth grade students, teachers, parents, and community stakeholders (Technology Solutions, 2004). The overall purpose of the SFtG module was to provide elementary students numerous opportunities to enhance their problem-solving and critical-thinking skills as they design resolutions for real-world scenarios that affect ecosystems and habitats. The Small Fry to Go program was designed to offer inter-disciplinary connections across the curriculum for the content areas of Science, Mathematics, Reading, Language Arts, Writing, Social Studies, Health Education, Character Education, Technology, and Career Education.

Small Fry to Go was grounded in the employment of project-based and problem-based instructional practices aligned to state and federal standards (Technology Solutions, 2004). The major advantage afforded to students who are exposed to the SFtG model is to establish critical-thinking skills that emphasize the significance of preserving habitats and ecosystems while conserving resources and becoming environmental stewards. Small Fry classrooms, connected via Internet video, link students from Georgia to Florida to Maine to Alaska to share experiences and understandings of their natural worlds (Technology Solutions, 2004).

Another popular supplementary STEM instructional alternative certified by the state of Georgia is the LEGO to Build to Express (Newton, Leonard, Buss, Wright, & Barnes-Johnson, 2020). Elementary students who are exposed to LEGO education techniques increase their ability to become creative problem-solvers and innovative and imaginative thinkers. LEGO education also supports student mastery of abstract perceptions through hands-on experiences in a science laboratory setting. LEGO instructional activities and projects aid in the development of 21st century skills that include problem-solving strategies, collaboration, and communication. The LEGO curriculum demonstrates the connections and interactions that exist between science, technology, engineering, and mathematics as it relates to real-world issues. LEGO educational resources and manipulatives enhance students' mastery of science process skills such as asking questions, defining the problems, and designing solutions because of interactive engaging experiences.

In addition to the day-to-day classroom activities associated with the traditional curriculum, another crucial feature of Georgia's STEM program is the requirement for all certified schools develop and maintain relationships with multiple business partners to help support their respective STEM programs. These partners are expected to support the programs financially as well with providing partner volunteer opportunities with teachers, parents, and students (Carter, 2013; Georgia Department of Education, 2015; Lyons, 2016; Sanders, 2009).

To earn STEM certification through the Georgia Department of Education, schools must: (a) contact district officials, (b) conduct a Pre-STEM Assessment Walk (District Visit), (c) satisfy all criterion of the Georgia Department of Education STEM Certification Continuum/Checklist, (d) facilitate a Georgia Department of Education STEM Team Visit, and (e) submit the Georgia Department of Education STEM Application to demonstrate that they meet rigorous criteria, such as evidence of teacher collaboration, business and industry partnerships, high levels of mathematics and science instruction and an integrated, project-based STEM curriculum (G. Lyons, personal communication September 18, 2016; Georgia Department of Education, 2015; STEMgeorgia.org, 2016).

Each STEM certified school designated a lead teacher (liaison) or STEM Coordinator to operate as a contact resource for the district and the state as well as the primary individual for disseminating current information regarding STEM news, policies, guidelines, and initiatives (Roehrig, et al., 2019). The STEM school coordinator also ensures that the Georgia Department of Education STEM Program, and the school district's STEM Model is implemented and functioning within each STEM certified school (Georgia Department of Education, 2015). The STEM coordinator also collects the artifacts and documentation from the STEM certified schools to assure compliance with the STEM program. The coordinator assures the STEM certified schools have met all the requirements and procedural components affiliated with the Georgia Department of Education STEM Application, The Georgia Department of Education STEM Continuum/Checklist (see Appendix A) prior to a visit by the team from the Georgia Department of Education Special Program and Imitative Department (G. Lyons, personal communication September 18, 2016; Georgia Department of Education, 2015; STEMgeorgia.org, 2016).

Prior to a school becoming STEM certified, the Georgia Department of Education STEM team visits the school to observe and document whether the components of the Georgia Department of Education STEM Application and the Georgia Department of Education Certification Continuum/Checklist have been implemented at a level for the program to be submitted for certification, (Roehrig et al., 2019). Once the application has been approved and certification has been awarded to a school, annual documentation must be completed and maintained via the STEM Checklist. The Georgia Department of Education STEM team makes a review visit every 5 years to ensure that the program at the school is functioning at a satisfactory level and submits a Georgia Department of Education STEM Certification Continuum Packet (Georgia STEM, n.d.) to verify compliance (G. Lyons, personal communication September 18, 2016; Georgia Department of Education, 2016; STEMgeorgia.org, 2016).

In summation, the primary arguments for STEM-integration versus traditional Science and Mathematics education at the elementary level is the collaborative learning environment and the myriad of opportunities provided to students to observe how the scientific method can be applied to everyday life. STEM education gives students the opportunity to attain process skills such as computational and abstract thinking while focusing on the real-world applications of problem-solving strategies, (Hester, K., & Cunningham, C. 2007). Elementary school STEM education focuses on the introductory level STEM courses, provides awareness of the STEM fields and occupations through instructional techniques that include standards-based and structured inquiry-based classrooms that emphasize real-world problem-based learning that connects all four STEM disciplines. The next section is used to introduce other teacher-variables that could enhance or hamper learning which are considered when the integrated STEM program is used (National Research Council, 2014).

Integrated STEM Program

The Virginia Tech integrated STEM model promotes project-based and problem-solving instructional approaches that incorporates an engineering design processes (Sanders, 2009; Wells, 2013). This model is the premise utilized by the Georgia Department of Education (Ga DOE) as the STEM curriculum choice for elementary certified schools. The GA DOE has endorsed the Boston Museum's program of study: Engineering is Elementary (EiE) as the primary curriculum for STEM integration in elementary schools (Cunningham, 2015; Cunningham & Berger, 2014; Cunningham & Kelly, 2015; Georgia Department of Education, 2015).

The Engineering is Elementary Curriculum is compatible to the Georgia State Science Standards of Excellence and is designed to teach engineering skills and content by integrating with the science topics most taught in elementary school. EiE is not intended to replace the elementary science curriculum but to be infused into the state's and district's mathematics and science standards and curriculum. EiE consists of 20 cross-disciplinary units that extend the mastery of mathematics and science concepts (Ring, 2017). The engineering design process is formulated to fit with the instructional objectives affiliated with science topics such as Earth Science, Life Science and Physical Science. EiE also assimilates with English/Language Arts and Social Studies lessons via innovative and interactive protocols that incorporate real-world engineering challenges to enhance and refine 21st-century skills such as creativity and teamwork. Through participation in the EiE curriculum, students are provided with engaging, hands-on activities that lead to transformational learning. An overview of the Engineering is Elementary Standards is shown in Appendix B.

The integration of STEM programs in the elementary grades provide opportunities for student collaboration, communication, critical thinking, problem solving interaction, and engineering design exposure (Carter, 2013; Cunningham, 2015; Cunningham & Berger, 2014; Cunningham & Kelly, 2015; Sanders, 2009; Wells, 2008; Wells, 2013).

The EiE curriculum was crafted to be a supplemental resource for the purpose of integrating STEM into the content areas of science and mathematics at the elementary level (Carter, 2013; Cunningham 2015; Cunningham & Berger, 2014; Cunningham & Kelly, 2015).

The overall purpose of the EiE curriculum model was to (a) increase children's technological literacy; (b) improve elementary educators' ability to teach engineering and technology; (c) increase the number of schools in the United States that include engineering at the elementary level; and (d) conduct research and assessment to add to the current body of knowledge about engineering teaching and learning at the elementary level (Carter, 2013; Cunningham, 2009, 2015; Cunningham & Berger, 2014; Cunningham & Kelly, 2015; Sanders, 2009; Wells, 2008; Wells, 2013).

Traditional (Non-STEM) Curriculum

For this study, the curriculum taught in all non-STEM certified schools is identified as being traditional. The Georgia Department of Education developed standards of excellence and content area frameworks for each grade level for teachers to use to assure consistency in content and instruction (Georgia Department of Education, 2015b). The frameworks include skills and standards to be mastered and a timeline or pacing guide for instructional deadlines (Appendix C). The traditional curriculum encompasses (a) specific courses and the order that the courses must be taken to earn a diploma or degree and (b) actual content covered in the class. Courses are presented in a progressive order whereby each level is more challenging than the previous level of courses. Thus, students are expected to build and use their skills as they proceed through the curriculum (Beck, 2009).

The traditional curriculum standards for mathematics highlight a myriad of skills and competencies that should be cultivated, enhanced, and mastered by students. These practices rest on important processes and proficiencies with longstanding importance in mathematics education (Georgia Department of Education, 2015b). The first of the skills and competencies that are expected to be cultivated, enhanced, and mastered by the students are the National Council on

Measurement (NCTM) education process standards of problem solving, reasoning and proof, communication, representation and connections. The second set of skills and competencies are the strands of mathematical proficiency specified in the National Research Council's report, *Adding It Up: Helping Children Learn Math* (Kilpatrick, Swafford, & Findell, 2001). Also included are adaptive reasoning, strategic competence, conceptual understanding (comprehension of mathematical concepts, operations and relations), procedural fluency (skill in carrying out procedures flexibly, accurately, efficiently and appropriately), and productive disposition (habitual inclination to see mathematics as sensible, useful, and worthwhile) (Georgia Department of Education, 2015b).

Curriculum At-A-Glance

In the curriculums for mathematics and science for third through fifth grades, the STEM and non-STEM units were taught simultaneously within the respective groups as designed by the state of Georgia Department of Education (Georgia Department of Education, 2015b). The schools in this study utilize the same school calendar, and the respective instructional units are on the same pacing guide. Both STEM and non-STEM mathematics and science courses employ the Georgia Standards of Excellence as the foundation for instructional practices. The Engineering is Elementary curriculum is structured to correlate to common core standards that conform to the guidelines of the United States Department of Education and the new educational initiative outline in President Obama's 21st Century Educational Program. The units for both curriculums use the same standards, but the STEM curriculum (EiE) integrates an engineering design process component that enhances students' mastery of the content with real world applications and increased depth of knowledge capacity to extend student learning and growth that supports the development of critical thinking and problem-solving skills. The EiE curriculum utilized by STEM schools incorporate the following steps for all units and grade levels as an extension of the learning process: (1) Ask, (2) Imagine, (3) Plan, (4) Create, and (5) Improve.

Curriculum-At-A-Glance 3rd Grade Mathematics

As an example, the traditional curriculum for mathematics third grade focuses on four critical areas: (a) developing understanding of multiplication and division and strategies for multiplication and division within 100; (b) developing understanding of fractions, especially unit fractions (fractions with numerator 1); (c) developing an understanding of the structure of rectangular arrays and of area; and (d) describing and analyzing two dimensional shapes. Figure 10 represents the third-grade traditional mathematics curriculum.

Curriculum At-A-Glance 3rd Grade Science

The Third Grade Georgia Science Standards of Excellence (Georgia Department of Education, 2015b) for science engage students in making observations and using information they obtained to answer questions. The students' communication skills allow them to record findings, analyze data, and recognize the importance of keeping records of observations without making alterations. Third graders add and subtract whole numbers mentally, on paper, and with a calculator. They observe, construct, and measure objects using ordinary hand tools. They observe things with many parts and describe the ways in which the parts influence or interact with one another. They represent objects in the real world with geometric figures, number sequences, graphs, diagrams, maps, and stories. The students are expected to use the information to explain physical attributes of rocks and soils, understand how fossils provide evidence of organisms that lived long ago, describe ways in which heat energy is transferred and measured, identify features of plants and animals within the geographical regions of Georgia and recognize the effects of pollution on the environment.

Curriculum At-A-Glance 4th Grade Mathematics

The fourth-grade Mathematical Georgia Standards of Excellence (Georgia Department of Education, 2015b) consists of a variety of "processes and proficiencies" skills and competencies that fourth grade students should master. The first of these are the NCTM process standards of problem solving, reasoning and proof, communication, representation, and connections. The second are the strands of mathematical proficiency specified in the *National Research Council's report Adding It Up*: adaptive reasoning, strategic competence, conceptual understanding, procedural fluency, and productive disposition.

Fourth graders solve problems and explain the steps employed in resolving problems. Students utilized tangible manipulatives or images to support students' mastery of problem-solving concepts. A variety of strategies are provided to students to check their answers and extend learning for transfer of knowledge. Students in the fourth grade can reason abstractly and quantitatively that a number represents a specific quantity and connect the quantity to written symbols and create a logical representation of the problem, both the appropriate units involved and the meaning of quantities as it relates to whole numbers, fractions, and decimals. Students write simple expressions, record calculations with numbers, and represent or round numbers using place value concepts.

In addition, students construct viable arguments and critique the reasoning of others and make connections between models and equations as they develop mathematical communication skills modeled with mathematics. Students experiment with representing problem situations in multiple ways including numbers, precise mathematical vocabulary, drawing pictures, using objects, making a chart, list, or graph, and creating equations. Fourth graders employ appropriate tools when solving a mathematical problem such as measurement tools to understand the relative size of units within a system and express measurements given in larger units in terms of smaller units. Students are able to derive patterns or structure when utilizing calculation methods such as properties of operations and identify regularity in repeated reasoning regarding mathematical computations.

Curriculum At-A-Glance 4th Grade Science

The fourth-grade Georgia Science Standards of Excellence (Georgia Department of Education, 2015b) are designed to provide foundational knowledge and skills for all students to develop proficiency in science. The Project 2061's Benchmarks for Science Literacy and the follow up work, A Framework for K-12 Science Education were used as the core of the standards to determine appropriate content and process skills for students. The Georgia Science Standards of Excellence instructional focus encompasses hands-on, student-centered, and inquiry-based approaches. Fourth grade science literacy includes a sufficient understanding of fundamental science content knowledge, science and engineering practices, and the use of scientific and technological information.

The fourth grade Georgia Science Standards of Excellence engage students in constructing meaningful models that afford natural world application. They speculate about observations they make. Students add, subtract, multiply and divide whole numbers on paper, mentally, and with calculators. They list common materials for making simple mechanical constructions and for repairing things. Fourth graders gather and interpret data and use records, tables, or graphs to identify patterns of change. They write instructions and make sketches that allow others to carry out a scientific investigation. They determine whether a comparison is fair if conditions are different for each thing being compared. They question claims or statements made by people outside their field of expertise. The students used these skills to compare and contrast the physical attributes of stars and planets, model the effects of the relative motion of the Earth and moon around the sun, use weather charts/maps to predict weather events, conduct investigations about the water cycle and understand their relationship with heat energy, communicate information about the nature of light and sound, study the effects of balanced and unbalanced forces on an object, and describe the flow of energy in an ecosystem and the roles organisms play in a community.

Curriculum At-A-Glance 5th Grade Mathematics

The fifth-grade Mathematical Georgia Standards of Excellence (Georgia Department of Education, 2015b) describe varieties of expertise that mathematics educators at all levels should seek to develop in their students. These practices rest on important "processes and proficiencies." The first of these are the NCTM process standards of problem solving, reasoning and proof, communication, representation, and connections. The second are the strands of mathematical proficiency specified in the National Research Council's report *Adding It Up*: adaptive reasoning, strategic competence, conceptual understanding, procedural fluency, and productive disposition. Students are expected to solve problems by applying their understanding of operations with whole numbers, decimals, and fractions including mixed numbers. They solve problems related to volume and measurement conversions. Fifth graders reason abstractly and quantitatively as they connect quantities to written symbols and create representations of problems using appropriate units involved and the meaning of quantities. Students write simple expressions that record calculations with numbers and represent or round numbers using place value concepts. Fifth graders construct viable arguments using objects, pictures, and drawings, and justify calculations based upon models and properties of operations and rules that generate patterns. They demonstrate and explain the relationship between volume and multiplication using models that represent problem situations in multiple ways including numbers, precise mathematical language, drawing pictures, using objects, making a chart, list, or graph, creating equations, and connect the diverse illustrations and explain the connections.

Fifth graders should also be able to evaluate results in the context of the relevancy to the situation. They also evaluate the utility of models to determine which models are the most efficient to solve problems. They use appropriate tools strategically when solving a mathematical problem such as using unit cubes to fill a rectangular prism or a ruler to measure the dimensions, and graph paper to accurately create graphs and solve problems or make predictions from real world data. Students also use precise terminology when referring to expressions, fractions, geometric figures, and coordinate grids, and specify units of measure and symbols.

Fifth grade students also discover patterns or structure for properties of operations as strategies to add, subtract, multiply and divide with whole numbers, fractions, and decimals in regard to numerical patterns and graphical representations. Students also employ repeated reasoning strategies to master algorithms' concepts and generalize about patterns. In addition, students connect place value operations with algorithms to fluently multiply multi-digit numbers and perform all operations with decimals to hundredths. Students explore operations with fractions with visual models and begin to formulate generalizations.

Curriculum At-A-Glance 5th Grade Science

The fifth grade Georgia Science Standards of Excellence (Georgia Department of Education, 2015b) establish essential background concepts and skills that students must master to become science proficient. The fundamental premise of the Georgia Science Standards of

Excellence was formulated from two groundbreaking resources: The Project 2061's *Benchmarks for Science Literacy* and the *A Framework for K-12 Science Education*. The Georgia Science Standards of Excellence focus on science and engineering practices and scientific inquiry design.

The Georgia Science Standards of Excellence instructional base includes hands-on, student centered, and inquiry-based approaches. Fifth grade science literacy entails an understanding of fundamental science content knowledge, science and engineering practices, and the use of scientific and technological information. The fifth grade Georgia Science Standards of Excellence engage students in investigations of scientific concepts using hands-on activities to discover and explain phenomena regarding the natural world. Additionally, these standards allow students to conduct experiments and report their findings in the form of written reports, charts, and various other presentations including multi-media projects. Fifth graders keep records of investigations and observations and understand why they should not alter records. They use numerical data to describe and compare objects, convert the fractions to decimals in scientific calculations. They use reference books, magazines or newspapers, and computer databases to locate scientific information. Students at this grade level can identify the causes of some of Earth's surface features, explain the difference between a physical and a chemical change, investigate electricity relationship between them, use scientific procedures to classify organisms, understand the difference between behaviors and traits, contrast the parts of animal and plant cells, and argue from evidence on how microorganisms can be beneficial or harmful to other organisms.

The Impact of Teachers' Expectations and Self-Efficacy on Academic Performance

In addition to the strategies, methods, and theories discussed previously, it is also possible that the integrated STEM program works because the teachers expect it to do so, and they feel as though they were able to successfully teach their students (Bruce-Davis et al., 2014; Mosely, 2015; Nadelson et al., 2013; Nathan, Tran, Atwood, Prevost, & Phelps, 2010; Ricks, 2012; Thomas, 2014; Tice, 1999). This level of confidence is a result of the professional development commitment the integrated STEM program mandates (Mosley, 2015). At the root of self-efficacy is a belief that the goals of the student and teacher can be achieved. Rosenthal and Jacobson (1968) were among the first educational researchers who showed how and why teachers' expectations could influence the students' academic performance.

Rosenthal and Jacobson's (1968) seminal research informed the educational community about the powerful influence teachers have on the academic performance of their students, knowingly or unknowingly. First, the researchers used deception in their study. The researchers reported that they debriefed the participants at the conclusion of the study. Rosenthal and Jacobson told the teachers there were late bloomers in their classrooms who were expected to show remarkable intellectual progress during the semester. In actuality, the researchers randomly selected the students from the school's records.

Rosenthal and Jacobson (1968) received support for their hypothesis. At the end of the semester, results revealed that the students identified as late bloomers showed an increase in their academic performance. The researchers then embarked on a mission to find out why the change occurred. After interviewing the teachers and students, the researchers concluded that the teachers' expectations influenced the students' behavior. For example, since the teachers were expecting their students to do well, they interacted in ways that would encourage and motivate the students to do well. Data showed that the teachers engaged the students more, spent more time with them on assignments, had more patience with the ostensibly late bloomers, challenged them and reinforced their behavior when they did good work. As a result, this theory is often referred to as the Pygmalion effect, where you literally get what you expect. The theory has been applied and supported in many different settings (Shaffer, 2009). It has also been consistently reported that a person's perceptions (i.e., cognitions, expectations, beliefs, interpretations) would influence their attitude and behavior (Baron & Branscombe, 2012).

Research has shown teachers who use the integrated STEM program expect their students to do well, and they believe that they had a positive effect on their academic development of their students (Bruce-Davis, et al., 2014; Mosley, 2015; Nathan et al., 2010; Thomas, 2014). Mosley (2015) designed and conducted a qualitative investigation to collect information about the teachers' perceptions. Mosley asked the teachers about their perceptions related to the instructional strategies they used for mathematics to implement the Common Core Standards (CCS). She also asked the teachers about their level of self-efficacy as related to the implementation of the CCS supported by the school. Data collection techniques included observations of the six teachers in the classroom, interviews, and focus groups.

Three of the four significant findings from Moseley's (2015) research relate to this proposed investigation. Results showed that the teachers (a) reported that they felt confident and comfortable with the implementation of the new curriculum; (b) told the researcher that they utilized a different instructional method (i.e., a balanced instructional method) than the one the researcher observed them use in the classroom (traditional); and (c) recognized that professional development experiences were important and that there was a need for professional development experiences. This information was collected as the teachers discussed the benefits and challenges, they perceived from using the CCS as the guide to instruction and learning mathematics.

Nathan et al. (2010) pointed that if the goal were to effect positive changes in the practices and decision making done by faculty as related to career success, college preparation, and instruction in engineering, then the beliefs and expectations of the teachers about engineering would need to be understood. The responses from STEM teachers in high schools indicated that the students' family background, interests, and previous academic achievement influenced their instruction. The participants also revealed they believed a student who was interested in the development of a career in engineering would need to show high academic achievement in both mathematics and science. Other teachers reported "mathematics and science content were integrated into engineering activities" (Nathan et al., 2010, p. 409). It was interesting to note these researchers also found there was a difference between what the teachers sometimes did versus what they said, which was like Mosley's (2015) findings. For instance, when asked directly if their students' socioeconomic status influenced their instruction, they said *no* (Nathan et al., 2010). However, when they responded to fictional vignettes, the socioeconomic status of the students influenced the situational decision-making tasks they were given. The implications from the findings were (a) some of the beliefs and expectations of the teachers' present challenges for STEM integration, and (b) education in engineering is viewed as a field for a limited few. Nathan et al. (2010) concluded these type beliefs could have a negative impact on the practices of recruitment, instruction, and evaluations for engineering students.

Teachers' perceptions about their students inevitably influenced their interactions with the students (Baron & Branscombe, 2012; Museus et al., 2011; Nadelson et al., 2013; Rosenthal & Jacobson, 1968). Bruce-Davis et al. (2014) also provided support for this conclusion. Bruce-Davis et al. interviewed administrators, students, and teachers to obtain information about their perceptions about the curricular and instructional practices and strategies in their schools. The following three themes were identified as a result of the participants' responses to the interview questions:

1. Each group of participants (administrators, students, and teachers) identified a vision that was similar, that is, they viewed the STEM high school as a learning environment that was challenging and engaging.
2. There was a focus to apply the instructional and curricular practices and strategies to problems in the real world.
3. Each group also expressed an appreciation for both the academic and affective support in the learning environment that was challenging.

STEM education is needed and critical for the future of the United States (Becker & Park, 2011). Becker and Park estimated 75% of occupations that were rapidly growing would require significant training in Mathematics and Science. It has been reported that the integrated STEM program has a positive influence on the interest and learning in STEM courses (Becker & Park, 2011; Mosely, 2015; Robinson et al., 2014; Sahin et al., 2014). In order to be adequately prepared for a career in a STEM field, it has been recommended that educators and community partnerships start early (Robinson et al., 2014; Watters & Diezmann, 2013). The conclusion by Robinson and colleagues was that students would be prepared for the global economy in the 21st century with STEM learning experiences.

Summary

Students need a solid foundation in the STEM field so they can develop careers related to science, technology, engineering, and mathematics. (Franco & Patel, 2017). There is a need for research to document and evaluate the integration of STEM disciplines on the academic achievement levels of American students (Becker & Park, 2011). As indicated by the Mohr-

Schroeder, Bush, and Jackson, (2018) too few students are prepared for STEM careers by the time they reach college. Consistent with this statement by the USDOE, data from the Becker and Park (2011) study showed “With respect to the grade levels, the effects of integrative approaches showed the largest effect size at the elementary school level and the smallest effect size at the college level” (p. 23). Thus, there is evidence that an interest and knowledge of STEM fields should start early in the students’ educational process. This chapter reviewed literature related to this study and to the framework that underpins the study. Additionally, this chapter reviewed the integrated STEM models and programs, the traditional education curriculum, and teacher factors that could influence student success. The next chapter discusses the methodology that was used to conduct the proposed investigation.

CHAPTER III

Methodology

The mixed method research process employed in this investigation was the explanatory sequential design because it adheres to a detailed protocol for testing hypotheses. The process starts with a theory or idea, which can be tested via an investigation. If the results of the experiment support the hypothesis, then the theory is strengthened and can be used to generate new hypotheses. The explanatory sequential protocol includes two important phases: Phase 1 - collection of quantitative data and Phase 2 - collection of qualitative data to explain or expound upon the quantitative findings. The basis for the explanatory sequential design in this study was to use the quantitative results as supporting evidence to the research hypotheses and questions; in turn, the qualitative data provided a rich explanation that was used to expound on the results (Creswell, 2009).

The current study was comprised of three datasets used to answer the research question, which centered around the impact of STEM integration on student achievement as measured by the Georgia Milestones End of Grade tests. The data sets consisted of student scale scores from the Spring 2016 Georgia Milestones Assessment System's End-of-Grade mathematics and science tests for 3rd, 4th, and 5th grades, and the Math and Science Content Questionnaire (MaSCQ), and semi-structured interviews. The MaSCQ served as a primary data set, while the interview responses helped to further explain these results (Creswell, 2014).

This chapter provides specific details about the research question addressed and the hypotheses tested. Additionally, the research design describes information about the population and selection of the sample, data collection and procedures to be used. Moreover, this chapter provides information about the validity and reliability of the study, data analysis measures and procedures.

Purpose of the Study

The purpose of this study was to examine the impact of a STEM integration program on third, fourth and fifth grade students' achievement scores in mathematics and science in an urban northeastern Georgia school district. The results of the study determined if significant differences exist between the students' achievement scores who were taught with the integrated STEM curriculum school and their counterparts who were taught in a traditional (non-STEM) mathematics and science curriculum school (independent variable). The study utilized the Georgia Milestones Assessment System's End-of-Grade mathematics and science tests administered in grades three to five in the Spring of 2016 along with the Math and Science Curriculum Questionnaire (MaCQ) with follow-up interview questions for further data analysis.

Research Question and Hypotheses

The overarching research question that guides this explanatory sequential mixed method study is: What effect did the integration STEM program have on third through fifth grade students' mathematics and science achievement scores in comparison to third through fifth grade students taught with the traditional mathematics and science curriculum?

The following hypotheses were evaluated:

$H1_0$: There is no significant difference between the mathematics achievement scores of third grade students in a mathematics class with an integrated STEM program and third grade students in a traditional mathematics class.

$H2_0$: There is no significant difference between the mathematics achievement scores of fourth grade students in a mathematics class with an integrated STEM program and fourth grade students in a traditional mathematics class.

$H3_0$: There is no significant difference between the mathematics achievement scores of fifth grade students in a mathematics class with an integrated STEM program and fifth grade students in a traditional mathematics class.

$H4_0$: There is no significant difference between the science achievement scores of third grade students in a science class with an integrated STEM program and third grade students in a traditional science class.

$H5_0$: There is no significant difference between the science achievement scores of fourth grade students in a science class with an integrated STEM program and fourth grade students in a traditional science class.

$H6_0$: There is no significant difference between the science achievement scores of fifth grade students in a science class with an integrated STEM program and fifth grade students in a traditional science class.

Research Design

This study employed an explanatory sequential mixed method research methodology comprising two data phases. The explanatory sequential mixed methods protocol consists of the initial analysis of quantitative data preceding the implementation of qualitative evidence. That evidence provides a deep analysis and creates astute justifications for the quantitative findings produced in a research study (Creswell & Plano-Clark, 2011). The utilization of a diverse research protocol supports triangulation of the historical data collected in this study. Research processes incorporate quantitative and qualitative statistical data to enhance the clarity and comprehension of the proposed problem and question being investigated (Creswell, 2014).

In the present study, a comparative analysis of mathematics and science students' achievement scores in a school district at the elementary level was based on the employment of two curriculum types: STEM and non-STEM (Traditional). The principal argument for this comparison between schools that incorporate the STEM curriculum (Engineering is Elementary) with the Georgia Standards of Excellence and non-STEM curriculum (Georgia Standards of Excellence) in the content areas of mathematics and science for third through fifth grades. To determine the impact of the school's curriculum on the 2016 Georgia Milestones Assessment System's End-of-Grade mathematics and science tests, the Math and Science Curriculum Questionnaire (MaSCQ) was administered to teachers who taught at the schools during 2015-2016 to gather further data for analyzation. Next, additional data was collected using online interview questions. School leaders selected the teachers who were interviewed.

A mixed method explanatory sequential research strategy is suitable for the present study because the responses provided by the focus group of STEM and non-STEM educators on questionnaires produced descriptive summations for the historical statistics collected by the researcher. An additional component of the questionnaire process includes follow-up interviews conducted with selected STEM and non-STEM teachers to ensure the clarity of the research question posed in this study was explained and to substantiate the six hypotheses established by the researcher.

Population and Sample

The population used in this study is from a school district in the southeastern part of the United States with many STEM certified schools. The state has 208 school districts that oversee educational policies and practices for 2,200 public, private, charter and specialty schools and facilities. Although the official school registry consists of 2,200 schools, only 29 schools have attained the Georgia Department of Education STEM certification and 19 out of the 29 certified STEM schools in the state of Georgia are STEM certified elementary schools.

The target school district provides educational services to a large and diverse student population. Although the participating school district's student enrollment population is large, only four elementary schools are classified as STEM schools certified by the Georgia Department of Education (Georgia Department of Education, 2015b). Approximately 450 third, fourth, and fifth grade students are enrolled at each of the four STEM certified schools, which equates to an approximate sample of 1,800 for those schools. The non-STEM curriculum schools have approximately the same student population in the third, fourth, and fifth grades. Thus, the total sample size for the quantitative portion for this study was 3,600 students. The sample group was approximately 1,200 third grader student scores, 1,200 fourth grade student scores, and 1,200 fifth grader student scores comprising the quantitative data component in this study.

Selection of Participants

The sample group consisted of student scores from eight schools: four elementary schools that have attained STEM program certification and four elementary schools that follow a non-STEM curriculum. The schools are all neighborhood schools and not magnet schools. Originally five STEM schools were asked to participate in the study but there were no MaSCQ responses from one of the STEM schools. The STEM certified schools are identified on the district's website as elementary schools that have achieved the Georgia Department of Education STEM certification in the selected district. The non-STEM curriculum schools were purposefully selected to ensure equivalent student populations (enrollment number, student demographics of gender, ethnicity and socio-economic status), and number of staff members. The data was accessed from the Georgia Department of Education School Report Card website.

Focus groups composed of STEM and non-STEM staff were also utilized in this study as a medium to rationalize and interpret the achievement scores of third through fifth grade students' Mathematics and Science scores based on the Spring 2016 End-of-Grade Administration. Responses acquired from questionnaires provided insight for the historical data that is analyzed. Two processes were employed in the acquisition of the qualitative responses from the four focus groups. Focus Groups one and two participated in a field-test process that provided structure and organizational formatting for a detail-oriented discussion process that produced phenomena and identified effective practices. The two focus groups employed in this study consist of the following compositions: Three non-STEM Instructional Liaisons (Focus Group One; and Three STEM Coordinators and Focus Group Two; four non-STEM Academic Coaches); 12 Teachers (Focus Group Three; 3rd, 4th and 5th Grade STEM Science Teachers and 3rd– 5th Grade non-STEM Science Teachers); Focus Group Four; 3rd, 4th and 5th Grade STEM Math Teachers and Focus Group Four; 3rd, 4th and 5th Grade STEM Math Teachers and 3rd, 4th and 5th Grade non-STEM Math Teachers). Therefore, the qualitative phase of this study consisted of four focus groups with a total of 20 STEM and non-STEM faculty members.

STEM School Participants Data

In this study there are student scores from four STEM schools. There were some specific questions asked to the STEM schools used solely for descriptive purposes. Each STEM school was asked about their STEM certification, program criteria and school/program participation selection. Each STEM school was asked whether they were STEM program certified or if they were whole school STEM certified. Three-fourths of the responses stated that they are whole school certified. Each school has been STEM certified for a minimum of 3 years. The school that is program certified did not go through the State of Georgia STEM requirements and/or did not meet all the standards to become a STEM school. The program certified schools do not implement STEM schoolwide. They can offer STEM as an extracurricular opportunity, as a designated day, or designated event at the school per semester.

Instrumentation

Phase I: Quantitative Phase. This phase consisted of two stages. The first phase of data collection began with the acquisition of quantitative ad hoc student achievement data from the State of Georgia Department of Education website to analyze the effectiveness of the curriculum programs (STEM and non-STEM Mathematics and Science) utilized in the targeted district. Prior to the collection of the data IRB approval was obtained from Valdosta State University (Appendix D). Although student achievement data can be statistically quantifiable, a second data collection phase, focused on teachers, was instituted to identify trends and to enhance insights via qualitative approaches such as reviews with focus groups of school leaders within the targeted populations and the administration of an online questionnaire and online interview questions (Creswell, 2014). The primary instrument used to collect data about student outcomes (i.e., dependent variable) is the Georgia Milestone Assessment System (Georgia Department of Education, 2016). The Georgia Department of Education (2016) worked to ensure that Georgia Milestone Assessment System adhered to the Standards for Educational and Psychological Testing that were established by the American Educational Research Association, American Psychology Association, and the National Council on Measurement in Education. The Georgia Department of Education (2016) explained that the most critical concern during the test development process was validity; however, they also recognized that an instrument would not be credible if it was not reliable (Georgia Department of Education, 2016).

Phase II: Qualitative Phase. This phase consisted of two stages. The first phase of data collection began with the acquisition of qualitative data from the MaSCQ Survey to analyze the effectiveness of the curriculum programs (STEM and non-STEM Mathematics and Science) and sample population in the targeted district. Although student achievement data can be statistically quantifiable, a second data collection phase was instituted to identify trends and to enhance insights via qualitative approaches. This approach consisted of interviews with school leaders from the targeted population as well as the administration of an online questionnaire.

I developed the semi-structured interview questions and the online questionnaire, and they were designed to answer the research question. To validate the interview questions and the questionnaire, four panel members were chosen to pilot test both sets of questions. Two members worked at a STEM school and two worked at a non-STEM school. The members were asked to review the questions and provide feedback. Minor adjustments were made as a result of the feedback.

Validity

Houser (2015) defined validity as the extent that the instrument "measures what it [was] designed to measure" (p. 229). The primary instrument used to collect data about student outcomes (i.e., dependent variable) is the Georgia Milestone Assessment System (Georgia Department of Education, 2016). The Georgia Department of Education (2016) worked to ensure that Georgia Milestone Assessment System adhered to the Standards for Educational and Psychological Testing that were established by the American Educational Research Association, American Psychology Association, and the National Council on Measurement in Education. The Georgia Department of Education (2016) explained that the most critical concern during the test development process was validity; however, they also recognized that an instrument would not be valid if it was not reliable (Georgia Department of Education, 2016).

Development of the test was considered a process that involved administrators, assessment professionals, and teachers (Georgia Department of Education, 2016). Educators in Georgia were placed on committees to provide feedback about the test items to ensure that they were in alignment with the curriculum, were appropriate and would not show any biases or sensitivity concerns (Georgia Department of Education, 2016). The Georgia Department of Education reported that each phase of the development of the Georgia Milestone Assessment System was carefully attended to so that validity could be ensured. According to the Georgia Department of Education, to ensure the validity of the Georgia Milestone Assessment System, each phase of the test development process was monitored carefully and documented. Georgia Department of Education (2016) concluded with the statement:

> The alignment of the Georgia Milestones with the state's content standards and the reliance of input from Georgia educators at every phase of test development are critical to the test's validity. In addition, the department is collecting evidence through separate independent alignment studies to ensure that the test measures the state's content standards. The validation of the test is an ongoing process. (p. 3)

As explained by the Georgia Department of Education (2015a), this attention to details was used to obtain both the internal and external validity of the Georgia Milestone Assessment System. Other threats to validity have been identified. The academic exploration protocol as described by Williams (2006) stated that all researchers bring several biases to a study and must endeavor to ensure objectivity and validity of their results. Williams also articulated that the researcher should demonstrate objectivity regarding appropriate documentation of data via accurate and reliable analysis of the findings in the study. Locke et al. (2009) suggested that the function and purpose of the researcher must be exposed in a study to represent transparency of the techniques and strategies employed to ensure that the findings and results presented are reliable and valid. The researcher worked to ensure that she approached the research process with objectivity and transparency and documented each phase of the scientific method that was used to conduct the study.

Curriculum implementation was identified as a threat to the internal validity of the study. While the Georgia Department of Education (2015b) sets standards for the integrated STEM program and traditional curriculum implementation, it cannot be known how the teachers implemented the programs during the 2015-2016 academic school year. Thus, internal validity was a limitation for this study.

Reliability

The Georgia Department of Education (2016) provided information about the reliability of the Georgia Milestone Assessment System. One measure that was used to assess the reliability of the Georgia Milestone Assessment System was Cronbach's alpha reliability coefficient. When the Georgia Milestone Assessment System was administered in the spring of 2015, reliability coefficients for the Georgia Milestone Assessment System for all students revealed that none of the reliability coefficients for the third through eighth grades were: (a) lower than .87 for English/Language Arts with the highest being .92, (b) lower than .91 for Mathematics with the highest being .93, (c) lower than. 88 for science with the highest being .93, and (d) lower than .89 for social studies with the highest being .93 (Georgia Department of Education, 2016). Measurements of reliability included tests that were administered in the paper and pencil format as well as online versions.

Comparability of Curricula in Treatment

All public schools in the state of Georgia are required to teach the Georgia Standards of Excellence. Each school is given the autonomy to choose supporting resources, including books, curriculum, and technology applications. The GSEs for grades 3, 4 and 5 are the primary standards for both STEM and non-STEM mathematics and science programs participating in this investigation. Both STEM and non-STEM school mathematics and science programs are grounded in the GSEs that are endorsed by the state of Georgia and the targeted district employed in the present study.

The difference between the STEM curriculum and the non-STEM curriculum is that the STEM schools use the Engineering is Elementary (EIE) program and it is embedded with the GSE standards. The STEM curriculum (EiE) integrates an engineering design process component that enhances students' proficiency in the content with real world applications and increased depth of knowledge. This is an enhancement to the state curriculum as the focus is task oriented to teach students to think critically, use problem solving strategies and some project-based learning. Whereas, the non-STEM classes have a traditional textbook, the STEM classes are more project-based and allow for application to real world scenarios using the Engineering in Elementary program.

Traditionally, education has been about learning by way of knowledge and memorization. STEM classes are different in that application is most important. These classes use project-based lessons so that students can apply what they have learned. For example, quizzes and tests are typically based on memorization. Studying consisted of trying to retain the information you would be tested on. In a STEM setting, knowledge retention is important; however, the way students apply that knowledge is just as important. STEM focuses not only on teaching a student about a subject, but also showing the student how the subject applies to real life, and how they will be able to utilize it in the future. For example, a traditional math course may teach a student an equation, but the student may not know how to apply that equation to real-life situations. A STEM program would teach a student a math equation, and how it could be used in different fields such as science or engineering. In STEM classes there is a deeper focus on skills such as critical thinking and innovation.

STEM education strives to generate an interest in subjects such as science, technology, math and engineering, because it gets students more involved in doing, rather than just memorizing. Traditional education covers a general spectrum of subjects without focusing directly on or diving deeper into a select few. A STEM class gets students involved in activities that can be directly applied to the subject at hand, ultimately creating more student interest, and limiting redundancy. In addition, traditional education tends to be more structured, STEM limits repetitive lessons and allows students to be creative. STEM is aimed at stimulating the brain and giving it a free reign to create, rather than replicating what is already known.

Independent Variable

This study explores the impact of curriculum usage (independent variable) on mathematics and science academic achievement. The independent variables are (a) the integrated STEM program taught in four schools and (b) the non-STEM or traditional curriculum taught in four other schools.

Dependent Variable

The dependent variables for this study are the scores obtained by third, fourth, and fifth students in the eight identified schools on the Georgia Milestone Assessment System (GMAS) Spring 2016 (April) End-of-Grade standardized tests. The GMAS was developed to assess the competence of students in language arts, mathematics, science, and social studies (Georgia Department of Education, 2015a). For this study, only scores for mathematics and science were analyzed.

Integrity of Curriculum Implementation

The targeted school district also utilizes STEM coordinators at each STEM school to ensure the fidelity of the monitoring protocol of the STEM program. The STEM coordinator was responsible for providing professional learning sessions for teachers at the beginning of the school year. During the pre-planning week, all teachers are mandated to attend informational workshops based on the following STEM areas: guidelines and procedures, curriculum guides and pacing information, class schedules and school events, business partners' initiatives, and meeting dates. The STEM coordinator also ensures that STEM mandates are met via monthly review meetings to discuss uniformity content instructional practices, and school-wide events and activities. Monthly progress reports are presented to the principal and leadership team to ensure that STEM program operations are compliant with state guidelines and policies.

The researcher was granted permission to participate in the STEM monthly meetings. Questions were generated based upon the agenda's provided, teacher/coordinator conversations and the researcher's need for clarity. Moreover, as the coordinators submitted the agendas to the respective school administrative team, a copy was provided to the researcher, which are kept on file with all other collected research materials for no less than seven years in accordance with Valdosta State University's IRB policy.

Data Collection and Procedures

Phase I: Quantitative Data Collection

State standardized summative End-of-Grade achievement scores from the Spring 2016, Georgia Milestone Assessment was used as quantitative data in this investigation. The Spring

2016, End-of-Grade Administration in mathematics and science for 3rd, 4th and 5th graders enrolled at the four STEM certified elementary schools and from four other elementary schools with similar student demographics that teach the traditional curriculum were collected in this study. The data was retrieved from the Georgia Department of Education School Report Card link, which is available to the public as well as data secured from the targeted district administrators who can view the data for all schools by curriculum type, gender, grade level and/or subject area.

Specifically, the researcher accessed the state and district's databases to collect GMAS data for 3rd, 4th and 5th graders in the identified schools. The summative achievement scores for mathematics and science were downloaded from the databases and exported into an Excel spreadsheet program for uploading to the data analysis software for analysis.

School identifying codes were added to the data retrieved from the databases. The STEM schools were assigned a one to denote the curriculum and schools with a traditional curriculum were assigned a two. The individual schools were assigned an alphanumeric code from one to four and A to D. The first STEM school was 1A. The second STEM school was 2A. The first traditional curriculum school was 1B. The second traditional curriculum school was 2B and this pattern was followed throughout.

Phase II: Qualitative Data Collection

In addition to the historical data collected in this study, online questionnaires were utilized to secure responses from STEM and non-STEM faculty members to provide descriptive data that highlighted the instructional practices employed prior to the administration of the Spring 2016 (April) End-of-Grade Assessment. An informed consent letter (Appendix E) alluded to the following items: explication of the purpose of this mixed- methods study, participant's permission invitation, and the online survey link were emailed to each STEM and non-STEM participant within the sample population. The online questionnaires were disseminated to math and science teachers identified by the STEM coordinators and academic coaches at the STEM (Appendix F) and non-STEM schools (Appendix G) within the targeted school district. The questionnaire consisted of two sections: teacher demographics and teacher instructional practices. The demographic data were used for comparison purposes during the data analysis process to provide validation of patterns and themes identified from the historical data. The instructional practices' section included questions related to the aspects of the standard based instructional classroom which highlights the specific activities and strategies employed to teach the same math and science content units for the targeted district's STEM and non-STEM curriculum. Informed Consent was obtained for the participants prior to administration of the survey (Appendix H).

Specific questions regarding the following instructional modalities were queried: (1) the opening exercises; (2) the work period instructional delivery approaches and activities; and (3) the closing and lesson resolution components based on the same math and Science content units outlined in the curriculum mandated by the targeted district. Once the responses from the math and science teachers at the STEM and non-STEM schools were disaggregated and analyzed, follow-up discussions were scheduled with randomly selected participants.

The follow-up session employed an interview protocol that consisted of open-ended questions. The time-period for the interview session was 20 – 25 minutes in the form of face-to-face discussions which were conducted at each participating school site. All participants' permission to record the interview discussion was secured prior to the start of the interview session to preserve accuracy of responses (Appendix I).

Data Analysis

This mixed method explanatory sequential study employed the collection of quantitative and qualitative data collected as a mechanism to answer the overarching research question and six hypotheses posed in this research evaluation. Both quantitative and qualitative data analysis methods were utilized to synthesize results and confirm deductions. The research question and hypotheses investigated in this study were addressed jointly via the quantitative EOG data and MaSCQ online questionnaires, feedback from two focus groups composed of instructional specialist, mathematics and science teachers, and semi-structured online interviews from selected participants in the STEM and non-STEM schools in the targeted district. The overarching question in this study was ultimately resolved through the evaluation of communal outcomes produced during the multiple data phases utilized in this study and cross-referencing analysis throughout all statistical measures.

The quantitative analysis for the school's results on the 2016 Georgia Milestones Assessment System's End-of-Grade mathematics and science tests were performed through the use of the Statistical Package for the Social Sciences (SPSS). SPSS was used to test the research hypotheses for statistical significance by conducting a t-test.

$H1_0$: There is no significant difference between the mathematics achievement scores of third grade students in a mathematics class with an integrated STEM program and third grade students in a traditional mathematics class.

$H2_0$: There is no significant difference between the mathematics achievement scores of fourth grade students in a mathematics class with an integrated STEM program and fourth grade students in a traditional mathematics class.

$H3_0$: There is no significant difference between the mathematics achievement scores of fifth grade students in a mathematics class with an integrated STEM program and fifth grade students in a traditional mathematics class.

$H4_0$: There is no significant difference between the science achievement scores of third grade students in a science class with an integrated STEM program and third grade students in a traditional science class.

$H5_0$: There is no significant difference between the Science achievement scores of fourth grade students in a science class with an integrated STEM program and fourth grade students in a traditional science class.

$H6_0$: There is no significant difference between the science achievement scores of fifth grade students in a science class with an integrated STEM program and fifth grade students in a traditional Science class.

Descriptive statistics (i.e., measures of central tendency, percentages) were used to summarize the demographics so that a description of the students, instructional liaisons, and teachers whose data were included in the study. In addition to the disaggregation of the Georgia Milestone Assessment System quantitative data, online questionnaire responses and interview feedback were analyzed to develop themes, interpretations, and inferences derived from the discoveries and outcomes developed during the study. The current study utilized Dedoose, a computer-assisted mixed-methods data analysis software, to organize and manage qualitative analysis from MaSCQ and the interview questions. The MaSCQ responses and the interviews were uploaded and stored in a password-protected account. Dedoose software provided an electronic system to analyze the responses of the survey instrument and the transcripts for keywords and themes. This was an efficient way to manage the large amounts of data generated from this study. The use of Dedoose was also beneficial in that it allowed for easy organization of data and identification of patterns and themes.

Qualitative data from the online questionnaires distributed to the four focus groups of educators that consisted of instruction liaisons and teachers from STEM and non-STEM elementary schools were appraised using descriptive statistics to determine the mean, median, mode, standard deviation, percentages, frequency distributions, and variability. Moreover, descriptive statistical measures were implemented to establish explanations and enlightenments regarding the findings and conclusions produced during the investigation about the effectiveness of a STEM integrated curriculum on mathematics and science student achievement in elementary schools for students in third, fourth, and fifth grades.

Proportional analysis between the feedback from the four focus groups and online questionnaire responses acquired from STEM and non-STEM instructional liaisons and teachers in conjunction with the mathematics and science End-of-Grade scores acquired from the state's Georgia Milestone Assessment System were employed to triangulate the validity and reliability of the quantitative and qualitative data in this study. Data group similarities and variances were examined individually and collectively throughout the investigation to ensure generalizations of the findings.

Summary

This chapter describes details about the methodology and procedures that were used in this study. The purpose of the study, the research question, and the hypotheses for the study were reviewed. This chapter also included information about the targeted population, the sampling method, and the sample. As well as the research method and research design were described.

Next the reliability and validity of the methodology were discussed. Finally, the data collection procedures and the process for analysis were explained.

CHAPTER IV

Results

Data analysis for this explanatory sequential mixed methods study consisted of two phases: Phase I: Quantitative Analysis and Phase II: Qualitative Analysis. Phase I used scaled scores from the Georgia Milestones End of Grade test for third, fourth, and fifth grade students in the content areas of mathematics and science for both STEM and non-STEM schools. Phase II: Qualitative Analysis included two phases. The first part of phase II consisted of the MaSCQ Survey responses from STEM and non-STEM teachers at the targeted schools. Part two utilized teacher responses from the interview questions.

Findings

All quantitative analyses were performed using the Statistical Package for the Social Sciences (SPSS). Analyses of the data were described as related to obtaining information that were used to respond to the research question through testing the hypotheses. Data analyses were used to respond to the research question and the six hypotheses are subsequently explained. First, descriptive statistics were used to summarize the demographics so that a description of the students, instructional liaisons, and teachers whose data was included in the study is provided. Next, each hypothesis was tested in the following manner. The hypotheses were tested to determine if there were any significant differences between the mathematics achievement scores of third through fifth grade students in a mathematics class with an integrated STEM program and third through fifth grade students in a traditional mathematics class. The t-test for independent samples were used to identify any differences and the probability level of .05 were used to determine if any differences are significant. The employment of the independent sample t-test afforded group statistical data regarding the mean scores of the two groups utilized for this study: the experimental (STEM program) and the control (tradition program) groups (Cronk, 2012).

The research questions in this study were created by the researcher. The survey instrument mathematics and science Curriculum Questionnaire (MaSCQ) was used to provide qualitative analysis of the sample population demographics and the instructional practices used by third, fourth, fifth grade mathematics and science teachers. The analysis of the survey responses was used to develop patterns and trends that explain the statistical analysis derived from the 2016 Georgia Milestone Assessment System Administration for third, fourth, and fifth graders in the content areas of mathematics and science in the sample population of the five STEM schools and the five Traditional schools located in northeast Georgia. The results indicated that STEM integration into the mathematics and science curriculum that the state department developed produced a significant difference in the scores of mathematics and science students at the STEM schools over the students at the Traditional schools.

Phase I Quantitative Analysis

The statistical test used to evaluate the research hypotheses was the independent samples *t*-test. Archival data retrieved from the Georgia Department of Education for the Spring 2016 Administration of the End of Grade test was used to determine if there was a significant difference between the means of two groups for science and mathematics. The hypotheses were tested to determine if there were any significant differences between the mathematics achievement scores of third through fifth grade students in a mathematics class with an integrated STEM program and third through grade students in a traditional mathematics class. The t-test for independent samples were used to identify any differences and the probability level of .05 were used to determine if any differences are significant.

The following overarching research question guided this explanatory sequential mixed method study: What effect, if any, did the integration of a STEM program have on third, fourth, and fifth grade students' mathematics and science achievement scores in comparison to third, fourth and fifth grade students taught with the traditional mathematics and science curriculum? The result of each hypothesis is presented in the tables below.

$H1_0$. There is no significant difference between the mathematics achievement scores of third grade students in a mathematics class with an integrated STEM program and third grade students in a traditional mathematics class.

An Independent Samples t-Test was conducted to determine if the mean difference between students who received STEM instruction and students who received traditional instruction was statistically significant for mathematics. There was a statistically significant mean difference among 3rd grade students (N = 356) who received STEM instruction (*M* = 516.04, *SD* = 49.565) and 3rd grade students (N = 412) who received traditional instruction (*M* = 507.04, *SD* = 47.024), *t* (p = .010 p<.05, 2 tailed) in mathematics. Based upon these findings the null hypothesis was rejected. The students in the STEM classes scored higher on the third-grade assessment than the students in the non-STEM classes.

$H2_0$. There is no significant difference between the mathematics achievement scores of fourth grade students in a mathematics class with an integrated STEM program and fourth grade students in a traditional mathematics class.

An Independent Samples t-Test was conducted to determine if the mean difference between students who received STEM instruction and students who received traditional instruction was statistically significant for mathematics. There was a statistically significant mean difference among 4th grade students (N = 324) who received STEM instruction

(*M* = 507.08, *SD* = 46.591) and 4th grade students (N = 380) who received traditional instruction (*M* = 490.48, *SD* =3 5.893), *t* (p = .000 p<.05, 2 tailed) in mathematics. Based upon these findings the null hypothesis was rejected. The students in the STEM classes scored higher on the fourth- grade mathematics assessment than the students in the non-STEM classes.

$H3_0$. There is no significant difference between the mathematics achievement scores of fifth grade students in a mathematics class with an integrated STEM program and fifth grade students in a traditional mathematics class.

An Independent Samples t-Test was conducted to determine if the mean difference between students who received STEM instruction and students who received traditional instruction was statistically significant for mathematics. There was a statistically significant mean difference among 5th grade students (N = 355) who received STEM instruction (*M* = 510.43, *SD* = 41.995) and 5th grade students (N = 412) who received traditional instruction (*M* = 503.08, *SD* = 41.995), *t* (p = .018 p<.05, 2 tailed) in mathematics. Based upon these findings the null hypothesis was rejected. The students in the STEM classes scored higher on the fifth-grade mathematics assessment than the students in the non-STEM classes.

$H4_0$. There is no significant difference between the science achievement scores of third grade students in a science class with an integrated STEM program and third grade students in a traditional science class.

An Independent Samples t-Test was conducted to determine if the mean difference between students who received STEM instruction and students who received traditional instruction was statistically significant for science. There was a statistically significant mean difference among 3rd grade students (N = 355) who received STEM instruction (*M* = 510.43, *SD* = 43.61) and 3rd grade students (N = 412) who received traditional instruction (*M* = 503.08, *SD* = 41.00), *t* (p = .018 p<.05, 2 tailed) in science. Based upon these findings the null hypothesis was rejected. The null hypothesis was rejected. The students in the STEM classes scored higher on the third-grade science assessment than the students in the non-STEM classes.

$H5_0$. There is no significant difference between the science achievement scores of fourth grade students in a science class with an integrated STEM program and fourth grade students in a traditional Science class.

An Independent Samples t-Test was conducted to determine if the mean difference between students who received STEM instruction and students who received traditional instruction was statistically significant for science. There was a statistically significant mean difference among 4th grade students (N = 324) who received STEM instruction (*M* = 495.80, *SD* = 47.95) and 4th grade students (N = 379) who received traditional instruction (*M* = 485.47, *SD* = 41.209), *t* (p = .002 p<.05, 2 tailed) in science. Based upon these findings the null hypothesis was rejected. The students in the STEM classes scored higher on the fourth-grade science assessment than the students in the non-STEM classes.

$H6_0$. There is no significant difference between the science achievement scores of fifth grade students in a science class with an integrated STEM program and fifth grade students in a traditional Science class.

An Independent Samples t-Test was conducted to determine if the mean difference between students who received STEM instruction and students who received traditional instruction was statistically significant for science. There was a statistically significant mean difference among 5th grade students (N = 324) who received STEM instruction (*M* = 507.24, *SD* = 58.135) and 5th grade students (N=384) who received traditional instruction (*M* = 487.47, *SD* = 51.547), *t* (p = .000 p<.05, 2 tailed) in science. Based upon these findings the null hypothesis was rejected. The students in the STEM classes scored higher on the fifth grade science assessment than the students in the non-STEM classes.

Phase II: Traditional and STEM Curriculum Comparisons

Quantitative data from teachers was obtained via the MaSCQ , an online network questionnaire in Qualtrics, an online platform. An online platform was employed for the distribution of the surveys to ensure anonymity of the participants and to secure the data in an efficient manner. Qualitative data was obtained from individual follow-up interview questions for select STEM and non-STEM teachers were based on specific curriculum units for each grade level and content area. The MaSCQ was analyzed using Dedoose, a computer-assisted mixed-methods data analysis software.

Grades 3-5 STEM Mathematics Curriculum and Program Integration

The questions for the STEM schools were sent out to 30 teachers and 25 chose to participate. Each teacher in STEM that was asked to participate and that chose to participate had a class size between 25 and the state of maximum of 32. All the participants that answered were active classroom teachers. The results yielded that 66.7% of the teachers apply STEM scope program to integrate STEM into the third through fifth grade mathematics curriculums, while 33.3% use engineering program to integrate STEM into the third through fifth grade. The participants all stated that their students participate in mathematics and science enrichment opportunities and integrated mathematics instruction at least two times a week per mathematics and science class. All schools stated they offer enrichment and accelerated differentiated instruction opportunities.

All participants were asked to provide the names of the programs that were used in their STEM programs for instruction for the third through fifth grade mathematics curriculum. All 25 participants stated they utilized the Georgia Standards of Excellence curriculum as their core source. The supplemental instructional programs that were used are: Engineering is Elementary, the Stir Fry Stem Instructional Module, the Legos Instructional Module and STEMscopes.

Finally, schools were offered the opportunity to provide any additional details regarding the third through fifth grade STEM Mathematics Curriculum. The participants were asked to include information about the standards, units, and curriculum maps that they follow. This question consistently yielded answers with the same two responses from 25 participants: the STEM curriculum is based on My Mathematics and the Georgia Standards of Excellence.

Grades 3-5 STEM Science Curriculum and Program Integration

Each of the 25 participants stated that in addition to the Georgia Standards of Excellence for science they use the science component of Engineering is Elementary and STEMscopes. Furthermore, the results yielded that a problem-based inquiry system is integrated into the Science program as well. Additionally, it was stated by 33% of the participants that they received Picture Program science and other STEM materials from the National Teachers of Science Association. Although many of the participants are from varied schools, the programs were all purchased by the school district and disseminated to all the STEM schools. These items are used to supplement the science curriculum and STEM education in the participating schools.

STEM Program and Implementation Fidelity

The participants were asked about the fidelity and implementation of the STEM curriculum in the mathematics and science classes. They were asked to provide written responses to the following questions: How are teachers trained to implement STEM into the mathematics and science curriculum and what procedures are in place to monitor the fidelity of the mathematics and science STEM curriculum at your school?

Monitoring the fidelity of implementation includes the use of semi-scripted lesson plans, strict adherence to the lesson plans, adherence to the STEM program standards, artifacts of student work, and administration monitoring of the program. It was also noted that the artifacts of the student work are kept and added to the study of work for the STEM recertification process that takes place every five years.

STEM Program Collaboration

The participants were asked to respond regarding collaboration to one of eight options for the question: how do teachers collaborate on the implementation of mathematics and science units? Each participant was allowed to select all the responses that applied to their situation. None of the participants selected that there is no collaboration. None of the participants selected that there is collaboration, but it is not structured or planned. Three participants selected that teachers collaborate quarterly to plan the integrated lessons. Ten participants selected teachers share and co- create STEM activities and plan learning outcomes. Six participants selected the teachers collaborate a minimum of once a week to plan integrated lesson plans. Two participants selected teachers and administrators share and co-create STEM activities and plan learning outcomes. All 25 participants selected the school administration provide a common planning time for all teachers. Three participants selected collaboration to plan integrated lessons, share and co-create STEM activities as well as plan learning outcomes.

When asked if there was any additional information that could be provided regarding the fidelity of the curriculum implementation and teacher collaboration, three statements were submitted: a) we try our best to make sure a connection is made every week, b) The STEM committee plans the units for each grade level, and c) we have dedicated time during our common planning periods to work on and collaborate on anything related to STEM.

Traditional School Data

There were 24 traditional school responses in this study. The make-up of the traditional school participants includes four academic coaches/liaisons (16.66%); eight third grade teachers (33.33%); six fourth grade teachers (25%), and six fifth grade teachers (25%).

Traditional Mathematics Curriculum and Program Implementation

When the traditional participants were asked, what curriculum was used to teach mathematics, each responded that they use the curriculum map provided by the school district. The curriculum map is planned according to the respective grade level needs as indicated by the data sources such as EOG scores, pre and post test scores, and teacher input. They are based on the Georgia Department of Education's Standards of Excellence.

Furthermore, when the participants were given the opportunity to state any additional information regarding the mathematics curriculum and implementation, it was stated that mathematics is taught using a combination of workshops and the gradual release of responsibility models. Some tools that were used include various Power Point videos, Number Talks, the 3-Read Protocol, mathematics songs, and mnemonic devices.

Traditional Mathematics Instruction and Enrichment

The traditional school students participate in mathematics instruction through varied accelerated differentiation opportunities. Mathematics instruction is provided between two to four days a week depending upon the grade levels and other district mandated tests.

When the traditional participants were asked about enrichment 20 of the 24 participants responded regarding the third through fifth grades enrichment opportunities. Enrichment opportunities were provided in the form of extra credit, differentiated instruction and after school mathematics and science clubs.

Traditional Mathematics Technology Integration

Twenty-four traditional school participants responded regarding technology integration for third through fifth grade mathematics content. Participants were asked about computer usage and technology integration at their schools. Participants were able to select all answers that applied to their schools in the responses.

All the participants selected that computers use was commonplace in their schools. All the participants stated computer based online, mobile, virtual, and other technology tools are integrated into the traditional curriculum classwork. All the participants selected that tablets, Chromebooks, or laptop computers were used with mathematics and science specific applications.

None of the participants selected the statement that students are regular producers of websites, blogs, computer programs, videos, or classroom digital products in any format. None of the schools selected the use of graphing calculators was taught or used to solve problems in the third through fifth grade. None of the schools stated that probes were used to collect and analyze data.

The responses were all or nothing. Finally, when asked for any additional comments regarding technology usage and integration the traditional school mathematics teachers stated that they use the Georgia Standards as the primary component for instruction. The teachers also noted the use of afterschool tutorials and practice packets to support student learning used the Georgia Standards of Excellence. Moreover, 45.45% (11 teachers) stated that there is use of remediation packets for the students. It was not made clear if those packets were provided in an electronic format during the virtual learning period of the school district.

Traditional Fidelity of the Mathematics Curriculum

When asked how the mathematics curriculum was implemented with fidelity the 24 participants responded. Four participants stated that they have a scheduled collaboration at least once a week. Eight participants stated that they meet monthly to plan integrated lessons. Four participants stated the teachers share/co-create lesson plans and plan learning outcomes. Eight participants stated the school administration must provide planning time for the teachers. None of the participants selected the statement that the teachers collaborate at least weekly to plan integrated lessons, and share/co-create mathematics and science activities, and plan learning outcomes.

Participants were asked what procedures are in place to monitor the fidelity of the mathematics curriculum at your school? Administrative walk-throughs, formal and informal observations are completed in regular intervals. Walk-throughs and observations are followed up with feedback to the teachers with suggestions for growth and additional support as the administration deems necessary. Some schools provide collaborative planning time with instructional coaches and administration. Depending upon the flexibility of the school administration this varies from weekly to bi-weekly. Each school is required to use assessment data to drive daily instruction. School administrations are subject to Focus walks sponsored by the school district, which may lead to additional support, training, or monitoring for mathematics classes.

Traditional Science Curriculum and Program Implementation

There were 24 responses provided regarding the third through fifth grade science curriculum. The core of the science curriculum is taught using the Georgia Science Standards of Excellence. The Georgia Performance Standards for Science, and the curriculum that was written by the school district. Science, like mathematics, is taught using a combination of the workshop and gradual release responsibility model. The traditional science curriculum uses a combination of tools, BrainPop, PowerPoint Presentations, videos, and Discovery Education, to assist with making science relatable to the students. Teachers are also encouraged to provide and promote collaborative learning and teamwork among the students.

Traditional Science Instruction and Enrichment

As recently as the last three years, some of the traditional schools have started implementing the Engineering Design Process units using pedagogical methods based on a social constructivist view of learning. These units include contextual learning and problem-solving skills that are taught, re-taught, and fostered throughout the school year. The Engineering Design Process challenges help students to make real-world connections to the things that they are learning. Most of the Engineering Design Process activities involve small-group work that encourages students to consider more than one solution or idea and work collaboratively.

As the traditional schools are moving forward, the Engineering Design Process helps to develop students' communication skills and encourage them to share ideas in multiple ways: speaking, writing, drawing, and building. Because the Engineering Design Process is a form of project-based learning, it is being integrated into the current science instruction as a main tool for instruction and enrichment. The Engineering Design Process' engineering design challenges engage students in inquiry. As they analyze their own data and make decisions about their designs, students engage with content, hone their critical-thinking skills, and take ownership of their learning.

Traditional Science Technology Integration

Schoology is an online Learning Management System Platform that teachers use to create one website for students to receive instructions for daily agendas, tasks, class assignments, quizzes, tests, and homework. Teachers can also upload the aforementioned items, informational texts, articles, novels, videos, and google slides/power points for their students within this one single platform. Schoology has different features and instructional options for students with additional resources such as practice assessments, content tutorials, and homework help discussions. Teachers can evaluate and provide feedback to student work on the site, and then allow for students to apply the feedback and resubmit assignments to demonstrate growth. Additionally, the school district provides hot spots to low-income households who meet specific eligibility requirements. This allows students to use the ItsLearning Platform that is paid for by the district that has a multitude of learning applications.

Traditional Fidelity of Science Curriculum Implementation

Fidelity of implementation within the traditional science curriculum comes with the use of formal and informal assessments to monitor the science curriculum. Additionally, each school had representatives for third through fifth grade to attend science-based training and to redeliver those science trainings to the science department. Finally, assessment data is used to drive the daily instruction and that information is reflected in the teachers annual Teacher Keys Evaluation System. This cycle allows teachers the opportunity to evaluate and refine when needed to ensure that they are implementing the curriculum with fidelity.

STEM Schools versus Traditional Schools Survey Responses

STEM schools are formulaic. They focus on science, technology, engineering, and mathematics with strict requirements for implementation and fidelity. STEM schools are computer based, online and in many cases can be easily made into virtual classes. Their programs integrate the use of websites, blogs, digital programs, videos, and industry partners/speakers.

That transformation is only regarding the increase to the use of technology integration. In the traditional third through fifth grade mathematics and science curriculum, the focus is only on the Georgia Performance Standards. It had been the responsibility of the schools and the creativity of the teachers to integrate technology into the lessons. It had not been a mandate.

In the STEM schools there is a mandate to follow the Georgia Standards of Excellence, the Engineering is Elementary curriculum (mathematics), STEMscope curriculum (science), and the STEM mathematics and science Curriculums from the school district that promotes inquiry-based learning, critical thinking, real life application, and problem-solving skills. All of this had a strict expectation of implementation by the teachers. Teachers are required to document all the creation, collaboration, evidence, activities, and outcomes that are produced. All information is kept yearly for the recertification process that takes place every five years. Moreover, there is a STEM committee that helps to ensure that all teachers are adhering to the implementation of the mathematics and science curriculum.

In the traditional schools there is a requirement to follow the Georgia Standards of Excellence via the school district's curriculum map. The school district determined what is a priority standard and those are the standards that are taught the most or the longest in mathematics and science. These standards are taught using the creativity of the teachers and the textbooks that are provided by the school districts. Traditional schools are given common standards with the expectation that they are implemented using the common unit tests provided by the school district. These unit tests are used to measure growth and drive daily instruction – determining remediation or enrichment for students in mathematics and science.

Finally, traditional schools are required to attend school and district level professional development to assist in ensuring proper implementation of the Mathematics and Science curriculum.

In STEM school's implementation fidelity is ensured via the mandatory professional development training. These training courses are required during the summer, on district professional learning days, and on designated after school days. All training is pre-scheduled and documented for re-certification and re-delivery purposes.

In the traditional schools, fidelity implementation is similar in the respect that training is offered, documented, and re-delivered. The variances are the times of the offerings and the obligation of the teachers to take the training. The trainings that are offered in the summer are mandatory for the STEM teachers, whereas they are optional for the traditional schoolteachers. Additionally, it is not the obligation of the teachers to re-deliver or implement in the class any of the items that are learned in the summer classes by the traditional teachers. This is the exact opposite for the STEM teachers. There is an expectation that what is learned is implemented to the students to increase student growth and student learning.

Summary

This chapter provided detailed findings of the study. The purpose of this explanatory sequential mixed-methods study was to determine if there was a significant difference in mathematics and science academic performance of third, fourth, and fifth grade students using a STEM integrated curriculum versus a Traditional curriculum instructional approach.

Demographic factors such as years of teaching experience, role or content taught, and duration of STEM certification were also examined. Data analysis encompassed both quantitative and qualitative results to determine if a significant difference existed when STEM integration was used as an approach for mathematics and science instruction. The quantitative data from the Georgia Milestone Assessment System's End-of-Grade test scores provided information for the research question and six hypotheses. Qualitative data from the online survey, MaCQ and semi-structured interview questions produced support for the research question and the six hypotheses.

Results from the quantitative data indicated that there was a significant difference in the mathematics and science academic performance of STEM curriculum integration based upon the p-values of less than or greater than .05 derived from the two tailed t-tests for the six null hypothesis. The results from the MaCQ Analysis of the qualitative data provided analysis of the sample population demographics and the instructional practices used by third, fourth, fifth grade mathematics and science teachers. The analysis of the survey responses was utilized to develop patterns and trends that explain the statistical analysis derived from the 2016 Georgia Milestone Assessment System Administration for third, fourth, and fifth graders in the content areas of mathematics and science in the sample population of the five STEM schools and the five Traditional schools located in northeast Georgia. The results indicated that STEM integration into the mathematics and science curriculum that the state of Georgia Education Department developed produced a significant difference in the scores of mathematics and science students at the STEM schools over the students at the Traditional schools. Chapter 5 will present a summary of the study, a discussion of the findings, conclusions, and recommendations for the future.

CHAPTER V

Discussion

This study was conducted to fill a gap in the literature that exists in terms of the impact of a STEM-focused curriculum at the elementary level. Recent research has focused on STEM education at higher levels of education, and few studies have addressed the impact of a STEM education in elementary school. This chapter focuses on the results obtained from data analyses guided by the research questions. The literature review in chapter two, in conjunction with the research questions, guides an interpretation of the results of the study. Chapter five presents a summary of the study, findings, conclusions, and implications for practice and recommendations for future research.

This explanatory sequential mixed method study investigated the impact of a STEM integration program on third, fourth and fifth grade students' scores in mathematics and science in an urban northeastern Georgia school district. The focus was to identify if there was a significant difference in student achievement if students were taught with a STEM curriculum approach versus a traditional curriculum approach.

This study was based upon the researcher's experience and prior knowledge in working with the three levels of K-12 education (elementary, middle, and high School). Based upon the prior knowledge and experiences, the researcher observed progressive weaknesses in mathematics and science classes. A weak foundation at the early levels can lead to issues with mathematics and science in middle school. Subsequently, those years of mathematics and science issues transfer to the high school courses. STEM instruction develops problem solving and critical thinking skills. The students who participate in STEM instruction can foster analytical skills. STEM is not a silver bullet to fix a problem, but it is a critical component to help students foster analytical skills. If a foundation is created school wide in the formative years the students can excel and have a stronger foundation than those students who are taught the traditional curriculum only.

The overarching research question was: What effect will the integration of a STEM program have on third through fifth grade students' mathematics and science achievement scores in comparison to third through fifth grade students taught with the traditional mathematics and science curriculum? Variables of interest to the study are type of instructional approaches (STEM or Traditional), grade level (third, fourth, or fifth), and relation to academic achievement in mathematics and science.

To respond to the research question, information was obtained from testing the hypotheses (i.e., whether the hypotheses were rejected or accepted) combined with explanations and justifications regarding the effective instructional curriculum practices employed. Third, fourth, and fifth grade mathematics and science classes were used to develop a response that would address the academic performance of the students in the experimental group and those in the control group.

Summary of the Results

The results of the study determined if significant differences exist between the students' achievement scores who were taught with the integrated STEM curriculum school and their counterparts who were taught in a traditional (non-STEM) mathematics and science curriculum school (independent variable). In the study the following hypotheses were tested:

$H1_0$: There is no significant difference between the mathematics achievement scores of third grade students in a Mathematics class with an integrated STEM program and third grade students in a traditional Mathematics class.

$H2_0$: There is no significant difference between the mathematics achievement scores of fourth grade students in a Mathematics class with an integrated STEM program and fourth grade students in a traditional Mathematics class.

$H3_0$: There is no significant difference between the mathematics achievement scores of fifth grade students in a Mathematics class with an integrated STEM program and fifth grade students in a traditional Mathematics class.

$H4_0$: There is no significant difference between the Science achievement scores of third grade students in a science class with an integrated STEM program and third grade students in a traditional Science class.

$H5_0$: There is no significant difference between the Science achievement scores of fourth grade students in a science class with an integrated STEM program and fourth grade students in a traditional Science class.

$H6_0$: There is no significant difference between the Science achievement scores of fifth grade students in a science class with an integrated STEM program and fifth grade students in a traditional Science class.

An Independent Samples t-Test was conducted to determine if the mean difference between students who received STEM instruction and students who received traditional instruction was statistically significant for mathematics and science in grades third through fifth. Based upon these findings the null hypotheses were rejected. The students in the STEM classes scored higher on the mathematics and science assessments than the students in the non-STEM classes in all three grade levels.

In the second phase of the study, the participants were asked about the fidelity of the implementation of the STEM program. Most of them indicated that the program was implemented with fidelity. In STEM school's implementation fidelity is ensured via the mandatory professional development training. These training courses are required during the summer, on district professional learning days, and on designated after school days. All training is pre- scheduled and documented for re-certification and re-delivery purposes.

In the traditional schools, fidelity implementation is similar in the respect that training is offered, documented, and re-delivered. The variances are the times of the offerings and the obligation of the teachers to take the training. The training courses that are offered in the summer are mandatory for the STEM teachers, whereas they are optional for the traditional schoolteachers. Additionally, it is not the obligation of the teachers to re-deliver or implement in the class any of the items that are learned in the summer classes by the traditional teachers. This is the exact opposite for STEM teachers. There is an expectation that what is learned is implemented to the students to increase student growth and student learning.

Related Literature

This study has provided myriad data that can lead to meaningful conclusions. The findings of the study coupled with discussions from previous literature provide an opportunity to interpret the data. Efforts to improve science and mathematics education in grades K–12 are not new. Since the 1960s these efforts have included curriculum development projects, professional development networks, and the creation of national standards documents. The release of the Common Core State Standards for Mathematics (NGACPB, 2010) and the Next Generation Science Standards, the latter modeled on A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (National Research Council, 2011) have further focused the nation's attention on teaching and learning of these subjects. In engineering and technology, the emphasis had been on expanding attention to these disciplines at the pre-college level, including through development of educational standards and making the case that exposing students to the E and T of STEM had the potential to improve learning of science and mathematics.

Adding the Engineering is Elementary curriculum created a foundation for children to build upon. This foundation was created by building blocks such as problem-solving skills, the ability to relate ideas to one another even when those ideas seemed unrelated, as well as the promotion of reasoning skills by way of understanding the ability to deconstruct to reconstruct, facilitating the ideals of an engineer. The addition encouraged students to maximize their critical thinking by integrating an array of disciplines; mathematics and science skills were fostered and drawn upon in their hands-own practices, technological skills were honed by their acquisition of technological literacy. These students were able to maximize their understanding of several integral concepts through engagement with engineering because the foundation will draw them into asking more questions about the ways in which both physical and intangible concepts work and why the function as they do. According to Hester and Cunningham (2007), given the opportunity to have these skills embedded into their curriculum, the students were able to process information. The students learned to accomplish goals through individualistic thought processes which were creative, careful, and thoughtfully executed. Students were also able to learn from their failures, which spoke to the notion that students were able employ reasoning skills based in fully fleshed out thought, provoked by understanding a range of ideals learned through questioning what they may have already known. The learning that came from the failures allowed students to capture what was wrong, what their errors were and to create a plan of action to correct them (Hester & Cunningham, 2007).

Conclusion

STEM education is often identified for school improvement or reform, particularly in urban schools. STEM education has been a thriving educational initiative since 2009 despite research showing that STEM elementary schools achieved mixed student achievement results (Hansen, 2014; Judson, 2014; Heiten, 2014; McLain, 2015). This study was conducted to add to the literature on STEM education in elementary schools and two conclusions were drawn from the study outcomes. While STEM education has been utilized as reform for twenty-first century learning, this study provides an extension of previous studies that surveyed achievement data in elementary STEM schools. The expectation of this study was there a significant difference in the academic performance in students taught with STEM integrated curriculum versus those taught with a traditional curriculum. The STEM integrated curriculum is scripted and grounded in a technology and engineering foundation as opposed to the traditional curriculum which does not offer the same enrichment opportunity. The results of the first phase of the study indicated that the students in the mathematics and science classes scored higher on the Georgia Milestone assessments than did their counterparts in the non-STEM classes.

Therefore, the first conclusion of this study is that the STEM approach used by the schools in this district had a positive impact on student achievement scores in math and science. In investigating the End of Grade assessment scores on the Georgia Milestones students in grades third through fifth grades scored higher than comparable students who were taught in the non-Stem traditional classes. Based on previous studies, there have been contradictory results when STEM and non-STEM achievement scores were compared. Guzey et al. (2017) found STEM implementation to have little impact on standardized test scores of students in fourth to eighth grades. Guzey et al. found when looking at standardized test scores in both science and math, only one set of science tests were positively impacted at a level of significance from STEM education. Dickerson et al. (2014) also found STEM instruction to have no statistically significant impact on standardized test scores in English, math, or science. However, the focus of the study was not a full STEM-focused program, but a STEM pull-out program. This pull-out STEM program included students from grades four through six, and students who participated were bused for whole units of STEM instruction to another elementary school, which was a different implementation from the current study.

However, Acar, Tertemiz, and Tasdemir (2018) found math and science test scores to be significantly increased from the implementation of STEM education. Although not at the elementary level, this does show an example of STEM implementation having a positive impact on math and science standardized test scores. Kurt and Benzer (2020) compared schools with STEM instruction and those with traditional curriculum. These researchers found the STEM schools to have higher scores than the traditional schools. Additionally, Morrison, McDuffie, and French (2015) looked at the Algebra and Geometry standardized test scores of students at a STEM-focused school versus those students enrolled in a traditional program.

The second conclusion is based on the second phase of the study and indicates implementation of STEM with the required components does matter. The literature reviewed for this study indicated that there are a variety of approaches of STEM integration that researchers have recommended for improving STEM education. Many states have established rubrics and guidelines to improve the quality of STEM implementation through different forms of STEM integration. There is wide agreement within the research community that transdisciplinary approaches are the highest level of STEM integration as they provide real-world and authentic opportunities for students to engage in problem-based learning and project-based learning in STEM education. The literature, especially meta-analyses, identifies a need for continued STEM program evaluation in elementary schools to discover and support best practices in STEM education. Factors such as staff quality, certification, professional development, and professional support have been discussed as areas where adjustments can be made to improve the quality of STEM education. Additionally, while STEM-focused schools have historically been identified for secondary students in the United States, there is a growing number of elementary schools with a STEM focus (Sikma & Osborne, 2014). The findings indicated that the STEM schools that were used in this study adhered to the principles and guidelines necessary for STEM certification in Georgia. The integration of a STEM focused elementary level program in the targeted district in this study embraced a cross-curricular, critical thinking approach that incorporates science, technology, engineering and mathematics (STEM) into all content areas through engaged learning that provides a hands-on experience (Georgia Department of Education, 2010; Georgia Department of Education, 2016; Sanders, 2009; Wells, 2013). The Georgia Department of Education adopted the Virginia Tech (2005) integrated STEM education program, also known as the Purposeful Design and Inquiry (PD&I) model, as the STEM model of choice for school districts that attained state STEM certification. The PD&I model emphasizes project-based and problem-based teaching and learning (Wells, 2013).

This sequential explanatory case study enabled a comparison between STEM schools and non-STEM schools within the same district. Maintaining an effective STEM program requires a few components. In this study, collaboration and PD were consistent elements of STEM teaching and learning at each school. These elements were significant factors in the success of the STEM programs because they contributed to the confidence of the teachers, who then passed it on to their students. These components were not the focus in the non-Stem schools

Limitations

Limitations for this study were identified. The sample for this study was chosen from schools with similar demographic profiles such as: (a) number of students enrolled, (b) gender, (c) racial/ethnic demographics and (d) free and reduced Lunch status (e.g., socioeconomic background of the student population). Generalizations inferred from this study will require readers and researchers to examine student demographics, curriculum similarities and differences to assess whether the results might be applicable to other schools. Results can only be generalized to participants/schools that share similar characteristics to those in the proposed study.

Participants in this study were enrolled in a large school district in Georgia; therefore, it was the expectation of the researcher that a diverse sample of students and demographics was obtained. This study did not address all plausible alternative explanations for differences in mathematics and science student achievement measurements of an integrated STEM program in elementary schools as compared with traditional elementary schools (e.g., levels of intelligence, achievement motivation, parental involvement, socialization of boys toward the sciences and mathematics, and girls' attitudes toward the social sciences, humanities, or helping careers).

As a former teacher, it is my experience that teachers do not always teach every part of a curriculum in the exact same manner, therefore an additional limitation in this study is the fidelity of implementation of the curriculum by the teachers at the selected schools. The variances in the implementation of the curriculum are based on teachers' passions, prior trainings, knowledge and background to the STEM culture and curriculum. These variances may not have been expressed to the researcher or the STEM coordinator because they were not pre-existing qualifications for the positions. The Georgia Department of Education (2015b) sets the standards for the STEM integration program and traditional curriculum implementation. The Georgia Department of Education also sets expectations for how the programs are implemented. However, oversight and evaluation of both programs are at the local level, except for a 5-year on-site review of the STEM integration program by personnel from the Georgia Department of Education STEM department (STEMgeorgia.org, 2016).

Recommendations for Practitioners

The results of this study have implications for district and school leaders who are responsible for implementing STEM education. The intent of these recommendations is to augment the current use of STEM as a reform model, and to refine the purpose of STEM education as an engagement and exposure opportunity for more students despite the school they attend. Three recommendations are provided.

1. Implement a program evaluation structure with measurements of multiple indicators of success. As part of an annual process used by the district, it is recommended that STEM-focused schools participate in a program evaluation process that examines multiple data sources. Ongoing assessment of the STEM-focused school environments will allow administrators to identify strengths, challenges, and necessary enhancements.
2. A case study can be created of the STEM schools focusing on the instructional "Best Practices" to implement in the traditional schools to increase the mathematics and science scores on the standardized tests.
3. Develop professional learning networks of schools to ensure support and

accountability for executing STEM standards and the district's vision for STEM schools. This recommendation is for the district to build a STEM school network to keep a strong foundation and to assist other schools who want to implement STEM. It is also recommended that continuous training is provided to help traditional teachers convert to STEM. It is also recommended that English/Language Arts is included into STEM (STEAM).

4. Elementary schools across the state should investigate integrating STEM in all elementary schools.
5. Universities should also include STEM training in elementary teacher preparation programs.

Recommendations for Future Research

This study was limited because it focused on four STEM schools and four traditional schools in one school district in the state of Georgia. However, the findings of the study can impact other districts within the state and the nation that are focusing on a STEM curriculum. Based upon the findings, the following recommendations can be made to school districts who are interested in increasing mathematics and science scores using an integrated STEM curriculum:

1. A similar study should be conducted with a larger sample population in an urban school district to address differences that may exist between school district's implementation of STEM education in elementary schools.
2. A qualitative study should be conducted to address the potential benefits of a STEM-focused school on third, fourth and fifth grade students' attitudes towards math and science.
3. A longitudinal quantitative research study should be conducted, using a similar

elementary population, with consideration given to a longer-running program of a STEM-focused curriculum.

4. Research should be conducted addressing a STEM-focused education and its impact on other forms of standardized testing, or other tests in general.

5. A case study of a particular school, or a few schools, with a STEM-focused curriculum should be conducted to assess the perceptions of teachers, administrators, and students regarding STEM integrated curriculum.

Summary

The current study was conducted to fill a gap in the literature that exists regarding the impact of a STEM-focused curriculum in elementary schools. Recent research has focused on STEM education at higher levels of education, and few studies have focused on the impact of STEM education in elementary schools. This study provided insight into elementary student achievement in grades three to five, comparing STEM and non-STEM achievement results in mathematics and science. Results showed that achievement in the STEM schools was higher than non-STEM schools. The findings from this study are important catalysts for increasing STEM experiences. This could be pivotal evidence to widen the opportunities for students in non-STEM schools.

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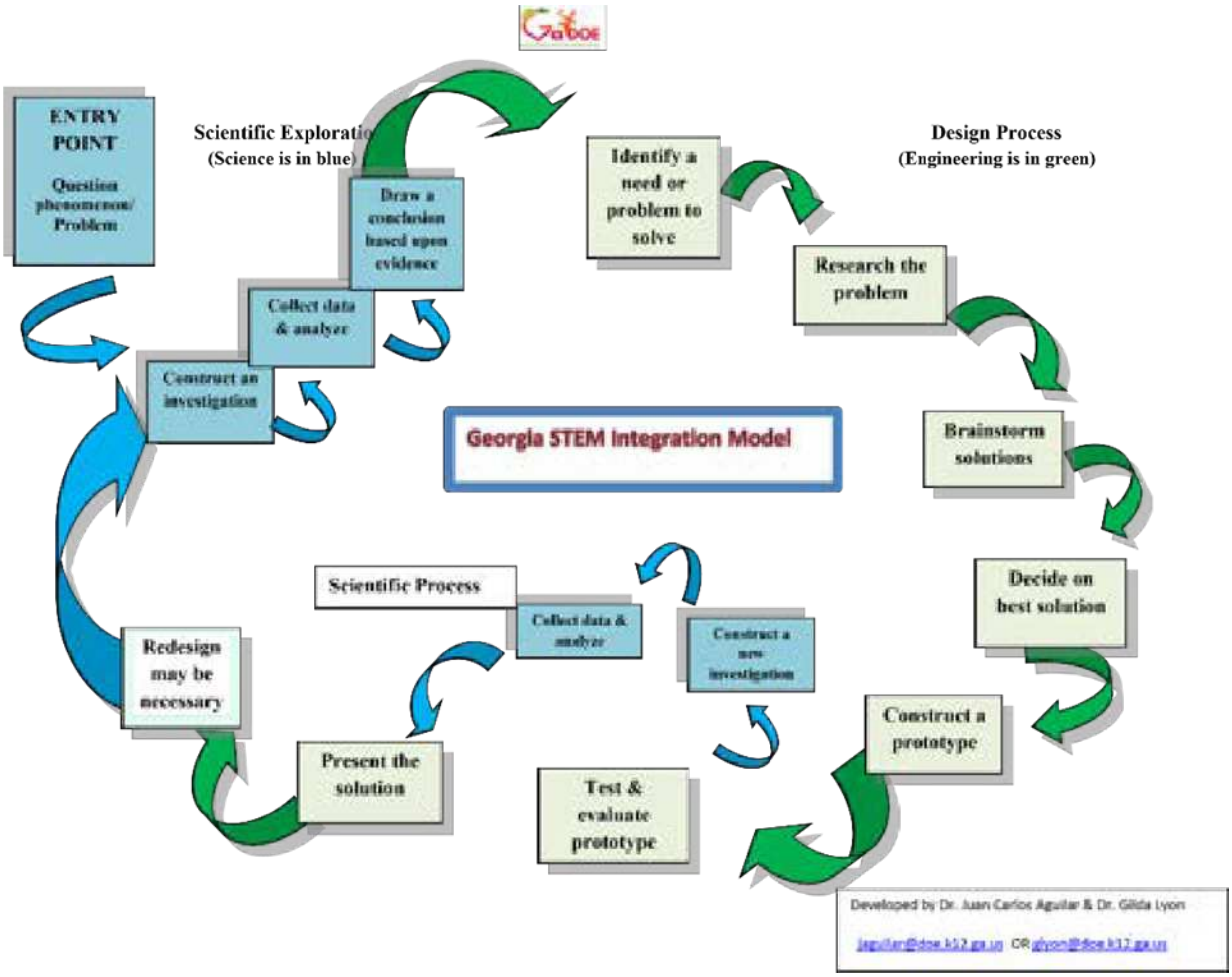
Appendix A

STEM Integration Model

STEM Integration Model



Appendix B

Engineering is Elementary Overview

Engineering is Elementary Overview

EiE Suggested Units by Grade for the Science Georgia Standards of Excellence
EiE teaches engineering skills and content by linking with the Science topics most commonly taught in elementary school. EiE is not intended to replace an elementary Science curriculum, but should be taught alongside related Science content. This table is designed to help users understand the units that are most appropriate for and integrate best with each grade level based on Science state standards. The units indicated are only suggestions. EiE is designed for grades 1–5, but because some units can be modified to the kindergarten level, we have provided kindergarten suggestions. Our reasoning for unit selection is based on the following criteria: ● Academic and age appropriateness ● Modifiability ● Standards alignment ● Materials management ● Unit content complexity for grade levels ● Unit repetition across grade levels EiE also integrates with language arts, math, and social studies content, so it is important to comprehensively review your curriculum, standards, and goals to determine which unit(s) integrate best for your situation.

Appendix C

Georgia Standards of Excellence Key

Georgia Standards of Excellence Key

MGSE: Mathematics Georgia Standards of Excellence (Grades 3-5)

Domain Key

NBT: Numbers in Operations in Base Ten G: Geometry
NF: Numbers and Operations, Fractions MD: Multiplication and Division
OA: Operations and Algebraic Thinking

SGSE: Science Georgia Standards of Excellence (Grades 3-5)

Domain Key
SE: Earth and Space Science SP: Physical Science
SL: Life Science

Appendix D

IRB Protocol Exemption Report

IRB Protocol Exemption Report

Institutional Review Board (IRB)
For the Protection of Human Research Participants
PROTOCOL EXEMPTION REPORT

PROTOCOL NUMBER:	03587-2018	INVESTIGATOR:	Rheanolia Wynn
		SUPERVISING FACULTY:	Dr. Gerald Siegrist
PROJECT TITLE:	*The Impact of STEM (Science, Technology, Engineering, and Mathematics) Integration Program on Third, Fourth, and Fifth Grade Students' Achievement in Mathematics, and Science.*		

INSTITUTIONAL REVIEW BOARD DETERMINATION:

This research protocol is **Exempt** from Institutional Review Board (IRB) oversight under Exemption **Category 2**. You may begin your study immediately. If the nature of the research project changes such that exemption criteria may no longer apply, please consult with the IRB Administrator (irb@valdosta.edu) before continuing your research.

ADDITIONAL COMMENTS:

- *The Research Statement of Consent must be read aloud to each participant at the start of recording. The Researchers voice must be part of the recording and the reading of the statement documented in the transcript.*
- *To keep within Exempt research guidelines – audiotaped interviews must be deleted immediately upon creation of each interview transcript.*

☒ ***If this box is checked, please submit any documents you revise to the IRB Administrator at irb@valdosta.edu to ensure an updated record of your exemption.***

Elizabeth W. Olphie 04.03.2018

Elizabeth W. Olphie, IRB Administrator Date

Thank you for submitting an IRB application.
Please direct questions to irb@valdosta.edu or 229-259-5045.

Revised: 06.02.16

Appendix E

Informed Consent Form

Informed Consent Form

November 1, 2017

The main purpose of this form is to provide information that may affect your decision about whether you want to participate in this research project. If you choose to participate, please sign in the space at the end of this form to record your consent.

WHO IS DOING THE RESEARCH?

Rheanolia M. Wynn, a doctoral learner under the direction of Gerald R. Siegrist, in the School of Education at Valdosta State University, is conducting a research study, titled The Impact of Science, Technology, Engineering, and Mathematics (STEM) Integration on Third, Fourth, and Fifth Graders' Mathematics and Science Achievement to assess the impact of the STEM integration program on third through fifth grade students' achievement in Mathematics and Science in an urban northeastern Georgia school district and is inviting you to participate in it.

WHAT DOES PARTICIPATION IN THIS RESEARCH STUDY INVOLVE?

If you decide to participate in this study, you were required to answer a series of questions in an interview and to complete and online survey. Your participation will take approximately a total of two hours. You were audio taped during your participation in this research.

WHY ARE YOU BEING ASKED TO PARTICIPATE?

You have been invited to participate because your position as an administrator or teacher directly involved with grades 3-5 Mathematics and Science curriculum implementation in one of the focus schools.

ARE THERE ANY RISKS INVOLVED IN THIS STUDY?

We don't anticipate any risks to you from participation in this study.

ARE THERE ANY BENEFITS TO PARTICIPATION?

The possible benefits of your participation in the research could help personnel in the school district as well as administrators at the eight schools (i.e., experimental and comparison groups) make evidence-based decisions. This study will provide school staff the opportunity to critically examine the variables that influence student achievement in Mathematics and Science within their respective schools, as well as to make comparisons between the instructional methods used. Additionally, the findings could contribute to a database that shows research-supported strategies to improve the educational status of American students. Moreover, the results of the study may be used to influence elementary school administrators and teachers to make effective decisions and implement strategic changes in the cultural and instructional practices to decrease the achievement gap. Thereby decreasing the gap for short- and long-term benefits to improve not only the status of students impacted by the school district in this study, but also to all STEM elementary schools.

HOW WILL THE RESEARCHER PROTECT MY CONFIDENTIALITY?

The results of the research study were published, but your name or identity will not be revealed. In order to maintain confidentiality of your records, the researcher will assign an alpha numeric character to your school and your position will not be disclosed in the summation of information.

WHAT HAPPENS IF I WANT DON'T WANT TO CONTINUE IN THE STUDY?

If you choose not to participate or choose to withdraw from the study, you may do so at any time. There was no penalty. It will not affect your school's overall summation.

WHAT WILL MY PARTICIPATION COST ME?

Your participation in the study will cost you approximately two hours of your time. There is no monetary value assigned to the interview and survey.

WILL I BE COMPENSATED FOR ILLNESS OR INJURY?

Agreeing to participate does not waive any of your legal rights; however, no funds have been set aside to compensate you in the event of injury. If you suffer harm because you participated in this research project, you may contact Rheanolia M. Wynn at (770) 310-9022 or you may contact the Chair of the Institutional Review Board through the Research & Scholarship Office at (229) 259-5045.

VOLUNTARY CONSENT

By signing this form, you are saying (1) that you have read this form or have had it read to you and (2) that you understand this form, the research study, and its risks and benefits. The researcher was happy to answer any questions you have about the research. If you have any questions, please feel free to contact Rheanolia M. Wynn at 770.310.9022 or via e-mail at rheanoliawynn@gmail.com. If at any time you feel pressured to participate or if you have any questions about your rights or this form, please call the Chair of the Institutional Review Board through the

Research & Scholarship Office at (229) 259-5045.

By signing below, you are telling the researchers “Yes,” you will participate in this study. Please keep one copy of this form for your records.

Your Name (please print):

Your Signature:

Date:

Appendix F

MASCQ Traditional School Questions

MASCQ Traditional School Questions

VALDOSTA STATE UNIVERSITY

MATH AND SCIENCE CURRICULUM QUESTIONNAIRE (MaSCQ)

SCIENCE TECHNOLOGY ENGINEERING ARTS MATHEMATICS

Greetings,

Please take a moment to provide responses to the questions listed below. Your feedback regarding 3rd - 5th grade math and science curriculum would be greatly appreciated.

Thank you for your cooperation regarding this matter. Please email any artifacts to: rheanoliawynn@gmail.com.

Many thanks!

Renee

Rheanolia Wynn

Is your school a traditional school or a STEM school?

- Traditional School
- STEM School

TRADITIONAL SCHOOL

TRADITIONAL SCHOOL: Demographics

TRADITIONAL SCHOOL: Please select your school.
Your responses will remain anonymous. School information will only be used to compare and contrast data.

- ○ Bouie Elementary
- ○ Dunaire Elementary
- ○ Redan Elementary
- ○ Marbut Elementary
- ○ Rock Chapel Elementary

TRADITIONAL SCHOOL: What is your role at the school?

- ○ Academic Content Liaison
- ○ 3rd Grade Teacher
- ○ 4th Grade Teacher
- ○ 5th Grade Teacher

TRADITIONAL SCHOOL: What is your focus?

- ○ Math
- ○ Science
- ○ Math/Science
- ○ Engineering
- ☐ Other (please specify below)

TRADITIONAL SCHOOL: What is your focus?

If you chose "Other" please explain.

TRADITIONAL SCHOOL: MATH AND SCIENCE ENRICHMENT AND TECHNOLOGY INTEGRATION

TRADITIONAL SCHOOL: Project / Problem-Based Strategies

- ☐ Our student do not participate in project/ problem-based learning activities. Students are only assessed using state and unit benchmark assessments Click to write Choice 1
- ☐ In addition state unit benchmark assessments, teachers use multiple indicators of success in math and / or sciencek innclubing knowledge and performance-based assessments.
- ☐ In addition to state, unit benchmarks, knowledge, and performance-baed assessment, shor and long-term project/problem-based activies are implemented and are moving toward student generated ideas.
- ☐ In addition to state, unit benchmarks, knowledge, and project/problem-based learning activities implementation and assessments, short and long-term projects/problem-based learning are implemented throughout the school year incorporating student-generated ideas that are standards-based, multidisciplinary, and real-world applications. Students are able to articulate the relationship that exists among the concepts learned in math and sciencess they create, develp, and synthesize their projecyd.
- ☐ Other (please specify below)

TRADITIONAL SCHOOL: Project / Problem-Based Strategies

If you chose "Other" please explain.

TRADITIONAL SCHOOL: Student Math and Science Enrichment

- ○ TRADITIONAL students participate in math and science enrichment opportunities. Students receive integrated math and science instrucbon 2-4 times per week.
- ○ TRADITIONAL students participate in math and science enrichment opportunities and are accelerated through differentiation. Students receive daily integrated math and science instructions.
- ○ Other (please specify below)

TRADITIONAL SCHOOL: Student Math and Science Enrichment

If you chose "Other" please explain.

TRADITIONAL SCHOOL: Student Math and Science technology Integration

- Computer use is commonplace
- Students are regular producers of websites, blogs, computer programs, videos, classroom digital products, and etc.
- Computer-based, online, mobile, virtual, and other technology tools are integrated into Traditional Curriculum classwork.
- Probes are used to collect and analyze data.
- Tablets are used with math and science specific apps.
- Graphing calculators are used to solve problems at the upper elementary level.
- Other (please specify below)

TRADITIONAL SCHOOL: Student Math and Science technology Integration

If you chose "Other" please explain.

TRADITIONAL SCHOOL: Any additional comments on opportunities provided for students in regards to student math and science enrichment.

TRADITIONAL SCHOOL: Grades 3-5 Math Curriculum

TRADITIONAL SCHOOL: Grades 3-5 Math Curriculum

What curriculum/program do you use to teach the 3-5 grade math ?

TRADITIONAL SCHOOL: Grades 3-5 Math Curriculum

Please provide details regarding the 3-5 grade Math Curriculum at your school (standards, units, and curriculum map copy). If possible, please email any artifacts to rheanoliawynn@gmail.com

TRADITIONAL SCHOOL: Grades 3-5 Math Curriculum

Any additional comments in regards to how math is taught to students?

TRADITIONAL SCHOOL: Grades 3-5 Science Curriculum

TRADITIONAL SCHOOL: Grades 3-5 Science Curriculum
Traditional Curriculum: What curriculum/program do you use to teach the 3-5 science curriulum?

TRADITIONAL SCHOOL: Grades 3-5 Science Curriculum
Please provide details regarding the 3 -5 grade Science Curriculum at your schools (standards, units, and curriculum map copy). If possible, please email any artifacts to rheanoliawynn@gmail.com.

TRADITIONAL SCHOOL: Grades 3-5 Science Curriculum
Any additional comments in regards to how science is taught to students?

TRADITIONAL SCHOOL: Fidelity of Math and Science Curriculum

TRADITIONAL SCHOOL: Fidelity of the Math and Science Curriculum
How are teachers trained to implemented the math and science curriculum?

- ○ Teachers have a scheduled collaboration at least monthly to plan integrated lessons, share/co-create math and science activities, and plan learning outcomes.
- ○ Teachers collaborate at least weekly to plan integrated lessons, and share/co-create math and science activities, and plan learning outcomes. The school administration must provide planning time for teachers.
- ○ Other (please specify below)

TRADITIONAL SCHOOL: Fidelity of the Math and Science Curriculum
How are teachers trained to implemented the math and science curriculum?
If you chose "Other" please explain.

TRADITIONAL SCHOOL: Fidelity of the Math and Science Curriculum
What procedures are in place to monitor the fidelity of the Math and Science Curriculum at your school?

TRADITIONAL SCHOOL: Fidelity of the Math and Science Curriculum
Any additional comments on the fidelity of the implementation and supervision of the math and science curriculum at your school.

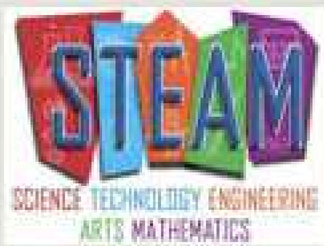
Appendix G

MASCQ STEM School Questions

MASCQ STEM School Questions

Valdosta State University

MATH AND SCIENCE CURRICULUM QUESTIONNAIRE (MaSCQ)



Greetings,

Please take a moment to provide responses to the questions listed below. Your feedback regarding 3rd - 5th grade math and science curriculum would be greatly appreciated.

Thank you for your cooperation regarding this matter. Please email any artifacts to: rheanoliawynn@gmail.com.

Many thanks!

Renee

Rheanolia Wynn

Is your school a traditional school or a STEM school?

- Traditional School
- STEM School

STEM School

STEM SCHOOL: Demographics

STEM SCHOOL: Please select your school.
Your responses will remain anonymous. School information will only be used to compare and contrast data.

- ○ Dunwoody Elementary
- ○ Henderson Mill Elementary
- ○ Hightower Elementary
- ○ Sagamore Hills Elementary
- ○ Hawthorne Elementary

STEM SCHOOL: What is your role at the school?

- ☐ Academic Content Liaison
- ☐ 3rd Grade Teacher
- ☐ 4th Grade Teacher
- ☐ 5th Grade Teacher

STEM SCHOOL: What is your focus?

- ○ Math
- ○ Science
- ○ Math/Science
- ☐ Engineering
- ○ Other (please specify below)

STEM SCHOOL: What is your focus?

If you chose "Other" please explain.

STEM SCHOOL: STEM Program Overview

STEM SCHOOL: How long has your school been officially STEM Certified?

- 0 – 3 years
- 4 – 5 years
- 6 – 9 years
- 10 or more years

STEM SCHOOL: Is your school whole school or STEM program certified?

- Whole School Certified
- STEM Program Certified

STEM SCHOOL: How are students chosen to participate in your school's STEM program?

STEM: STEM Student Math and Science Enrichment and Technology Integration

STEM SCHOOL: Project/Problem-Based Learning Strategies

- ○ Our students do not participate in projects/problem-based learning. Students are only assessed using state and unit assessments.
- ○ In addition to state and unit assessments, teachers use multiple indicators of succdax in a STEM content area; including knowledge and performance-based assessments.
- ○ In addition to state, unit, knowledge and performance-based assessments; short and long-term projects/problem-based learning strategies are implemented and are moving instruction toward student generated ideas.
- ○ In addition to state, unit, knowledge and performance-based assessment, and short and long-term project/problem-based learning strategies are implemented throughout the school year incorporating student-generated ideas that are standards-based multidisciplinary and real-world. Students are able to articulate the relationship among the concepts learned in math and science to their created projects.
- ○ Other (please specify below)

STEM SCHOOL: Project/Problem-Based Learning Strategies

If you chose "Other" please explain.

STEM SCHOOL: Student Math and Science Enrichment Opportunities

- ○ STEM students participate in math and science enrichment opportunities and receive integrated math and science instruction 2-4 times per week math and science instruction.
- ○ STEM students participate in math and science enrichment opportunities and are accelerated through differentiated instruction. Students receive daily integrated math and science instruction.
- ○ Other (please specify below)

STEM SCHOOL: Student Math and Science Enrichment Opportunities

If you chose "Other" please explain.

STEM SCHOOL: Students Math and Science Technology Integration Tools and Usage

- ○ Computer use is commonplace/are producers of websites, blogs, computer programs, videos, classrm digital products, etc....
- ○ Computer-based, online, mobile, virtual, and other technology tools are integrated into STEM classwork
- ○ Probes are used to collect and analyze data
- ○ Tablets are used with STEM specific appsw
- ○ Graphing calculators are used to solve problems at the upper elementary levels
- ○ STEM industry related technology is available for student use
- ○ Other (please specify below)

STEM SCHOOL: Students Math and Science Technology Integration Tools and Usage

If you chose "Other" please explain.

STEM SCHOOL: Student Math and Science Enrichment and Technology Integration

Any additional comments regarding opportunities provided for students in math and science technology integration enrichment.

Appendix H

Survey Consent Form

Survey Consent Form

You are being asked to participate in a survey research study entitled *"**The Impact of STEM (Science, Technology, Engineering, and Mathematics) Integration Program on Third, Fourth, and Fifth Grade Students' Achievement in Mathematics, and Science**,"* which is being conducted by *Rheanolia Wynn,* a *student* at Valdosta State University. The purpose of this study is to *determine if significant differences exist between the students' achievement (dependent variable) who were taught with the integrated STEM curriculum school (independent variable) and their counterparts who were taught in a traditional (non-STEM) Mathematics and Science curriculum school (independent variable).* This research study is anonymous. No one, including the researcher, were able to associate your responses with your identity. Your participation is voluntary. You may choose not to participate, to stop responding at any time, or to skip questions that you do not want to answer. You must be at least 18 years of age to participate in this study. Your participation serves as your voluntary agreement to participate in this research project and your certification that you are 18 or older.

Questions regarding the purpose or procedures of the research should be directed to *Rheanolia Wynn* at rrwynn@valdosta.edu. This study has been exempted from Institutional Review Board (IRB) review in accordance with Federal regulations. The IRB, a university committee established by Federal law, is responsible for protecting the rights and welfare of research participants. If you have concerns or questions about your rights as a research participant, you may contact the IRB Administrator at 229-259-5045 or irb@valdosta.edu.

Appendix I

Interview Consent Form

Interview Consent Form

You are being asked to participate in an interview as part of a research study entitled ***"The Impact of STEM (Science, Technology, Engineering, and Mathematics) Integration Program on Third, Fourth, and Fifth Grade Students' Achievement in Mathematics, and Science"***, which is being conducted by Rheanolia Wynn, a *student at Valdosta State University*. The purpose of this study is to *determine if significant differences exist between the students' achievement (dependent variable) who were taught with the integrated STEM curriculum school (independent variable) and their counterparts who were taught in a traditional (non-STEM) Mathematics and Science curriculum school (independent variable).* The interviews were audio taped in order to accurately capture your concerns, opinions, and ideas. Once the recordings have been transcribed, the tapes were destroyed. No one, including the researcher, were able to associate your responses with your identity. Your participation is voluntary. You may choose not to participate, to stop responding at any time, or to skip any questions that you do not want to answer. You must be at least 18 years of age to participate in this study. Your participation in the interview will serve as your voluntary agreement to participate in this research project and your certification that you are 18 years of age or older.

Questions regarding the purpose or procedures of the research should be directed to *Rheanolia Wynn* at *rrwynn@valdosta.edu.* This study has been exempted from Institutional Review Board (IRB) review in accordance with Federal regulations. The IRB, a university committee established by Federal law, is responsible for protecting the rights and welfare of research participants. If you have questions or concerns about your rights as a research participant, you may contact the IRB Administrator at 229-259-5045 or irb@valdosta.edu.