THE IMPACT OF STEM EDUCATION ON ELEMENTARY SCHOOL MATH AND SCIENCE ACHIEVEMENT

by

Jessica Bentley

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

Doctor of Education

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ABSTRACT

The following is a dissertation looking to address the impact of STEM-focused education on fifth-grade standardized test scores in mathematics and science. STEM education has become such an integral part of American education in recent years, and its importance continues to extend beyond the research available. The purpose of this quantitative study is to examine the effects of a STEM-focused education on the standardized test scores of students in fifth grade. Convenience sampling was employed, with matching, to collect data from four classes of fifth grade students, totaling 226 students, from a rural school district. The 2019 Virginia Standards of Learning assessments in math and science for fifth grade only were used as the data for the study. The researcher chose a causal comparative research design, as this lends itself well to research aimed at finding a cause-and-effect relationship. Archival data was used to address the research question, and MANOVA was chosen as the statistical test for analysis of the data. Data showed a significant difference between STEM-focused schools and schools with a traditional math science curriculum, $F(2, 223) = 8.289$, $p < .0005$; Wilks' $\Lambda = .931$; partial $\eta^2 = .069$, with the traditional schools having higher scores in both math and science on those standardized tests. While this study did not show a positive impact of STEM education on standardized test scores, many factors were addressed, including the variability of implementation of STEM education, longevity of programs, and lack of a clear definition of STEM education. Recommendations for future research include varied populations of students and mixed methods studies that could include the impact of STEM education on mathematical and scientific interest and confidence.

Keywords: STEM, STEM-focused education, inquiry-based learning

Copyright Page (Optional)

Dedication

I whole-heartedly dedicate this manuscript to my supportive husband, Matt, and loving daughter, Kennedy. Without my husband, this would never have been possible, as he took on the lion's share of responsibilities while I worked, and cheered me on throughout the process. There has never been an individual who believed in me more, and without his constant support, I would have been lost. To my daughter, my sweet Kennedy, who made me a mother and gave me the greatest joy in life, I dedicate this work to you. I hope that it can provide you with the inspiration to achieve anything you can think of in life.

Acknowledgments

To my committee chair, Dr. Struble, your positive encouragement suited my style of learning and working perfectly, and I truly appreciated your support throughout. Dr. Barthlow, my committee member and methodologist, your knowledge of statistics and willingness to help me learn pulled me through the difficulty of completing this dissertation. The supreme importance of a supportive faculty and committee through writing a dissertation cannot be overstated.

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List of Abbreviations

Adequate Yearly Progress (AYP)

Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science (America COMPETES)

English Language Learners (ELL)

Internal Review Board (IRB)

Integration of Science, Technology, Engineering, and Mathematics (iSTEM)

Multivariate Analysis of Variance (MANOVA)

National Defense Education Act (NDEA)

National Science Foundation (NSF)

Next Generation Science Standards (NGSS)

No Child Left Behind (NCLB)

Science, Technology, Engineering, Mathematics (STEM)

Standards of Learning (SOLs)

Statistical Package for Social Sciences (SPSS)

Students with Disabilities (SWD)

Virginia Department of Education (VDOE)

CHAPTER ONE: INTRODUCTION

Overview

This study examined the impact a STEM (science, technology, engineering, and mathematics)-focused curriculum had on fifth grade students' standardized test scores in math and science. The background included in Chapter One provides a brief history of STEM, legislation associated with STEM, and a theoretical perspective for STEM education. The problem statement addresses literature associated with STEM in education. The purpose of this study was to find, if any, the effect that a STEM-focused education may have had on fifth grade students' standardized test scores. The end of Chapter One includes an introduction to the research questions for the study and definitions applicable to this research.

Background

While trends in education tend to come and go, it seems that STEM education is here to stay. STEM stands for the integration of science, technology, engineering, and mathematics. Within recent years, many American legislators and government officials have become concerned with the direction of education in the United States (Arar et al., 2019). These STEM skills have become known as unequivocally necessary for the future workforce of America and the world alike (Bell et al., 2017). Government officials have become particularly concerned with this in terms of how American students compare to those in other countries. Some have become concerned that the United States may no longer be the global leader in the fields of science and technology (Xie et al., 2015). This concern has led those leaders to look closely at the way our educational system is encouraging students to learn more about these fields, and ultimately choose careers related to STEM (Wang et al., 2017). This has called the National Science Foundation (NSF), among other agencies, onto the scene, where the debate about what constitutes STEM education, and its importance to the educational system continues to be discussed by educators and legislators alike (Holmlund et al., 2018).

Historical Overview

In order to better understand STEM in education, one must look at America during the Sputnik era. In 1957, when the Soviet Union launched the first artificial satellite into orbit around the earth, it caused an uproar among Americans (Jolly, 2009). Many felt this proved that American students were falling behind those in the Soviet Union in terms of producing scientists and those interested in technical careers. These new concerns caused funding for education to change, standards to be looked at more closely, and the role of government in education to be reexamined. The National Defense Education Act (NDEA) was enacted in 1958, which was aimed at increasing funding for science and technical education in response to the space race (Clark, 2017). This effectively put technical and scientific education and careers at the forefront of the American mind.

In 1983, a government report called *A Nation at Risk* was presented by President Reagan's Secretary of Education, Terrel Bell. This report detailed how American schools were failing our children in many different areas. The report called for public schools to provide a more rigorous curriculum, with a specific focus on technology and science (Borek, 2008). Later, in 2007, President George Bush enacted Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science (America COMPETES) Act. This was intended to place more emphasis on science, technology, engineering, and mathematics in education, along with providing more funding and research towards these initiatives. This act even provided for the creation and implementation of specialized programs and schools geared towards STEM education (Thomas & Williams, 2009). By 2009, President Obama created the

Educate to Innovate campaign which was designed to strengthen STEM in education by creating 100,000 STEM-teaching jobs and increase student interest in STEM in education and STEM-related careers (Beilock & Maloney, 2015).

The term STEM was coined by the NSF in the early 2000s, which was a change from their original acronym SMET (science, mathematics, engineering, and technology). This terminology, since its inception, has been used by educators and legislators alike to describe the educational movement towards the inclusion and integration of science, mathematics, and technology (Holmlund et al., 2018).

Societal Impact

Without a doubt, there is a sense of importance placed on the United States being a leader in the global marketplace. Many believe that America is falling behind other countries in the fields of science and technology, and those individuals feel a strong need to put policy in place to correct this (Ashford et al., 2016). This belief has been fueled by an array of reports released indicating American students' poor performance on academic tests in science and mathematics (Gamse et al., 2016), along with research that indicates women and marginalized groups being underrepresented in STEM-related fields and careers (Habig et al., 2020).

Research indicates that along with this feeling of American educational failure in STEM education, fewer young people are choosing to pursue careers related to STEM (Smith & White, 2019). This has led educators and government officials to question the reason that STEM is not high on the list for most American students. One concern among both groups has become whether or not teachers are fully equipped to deliver high-quality, STEM-focused curriculum with their current training (Knowles et al., 2018).

Theoretical Background

John Dewey spent his career advocating for vocational education, touting its importance (Kett, 2017), and believing in experiential education and its benefits (Tarrant & Thiele, 2016). Dewey was an advocate of hands-on learning that would allow children to understand problems and come to solutions through interacting with their world. His beliefs are supported by inquiry-based instruction, which allows learners to gain knowledge through exploration, observation, predictions, and evaluations (Hollingsworth & Vandermaas-Peeler, 2016). Through inquiry-based instruction students are able to construct their own knowledge, while being guided by an instructor, making rich and meaningful connections along the way. This type of instruction is particularly useful in teaching science and engineering concepts, as these are based in the natural world and supported by hands-on learning (Hollingsworth & Vandermaas-Peeler, 2016). Research indicates inquiry-based education can be more effective than other more traditional methods of instruction in terms of students acquiring content knowledge and demonstrating application of gained knowledge (Lazonder & Harmsen, 2016).

STEM education lends itself well to inquiry-based education. When students engage in true STEM activities, units, and learning situations, they are actively inquiring and exploring the world around them through a process that makes a connection between science, math, and technology and the real world (DeCoito & Myszkal, 2018). Engaging children in their own learning, allowing them to make meaningful connections, allowing for the construction of knowledge, is of so much importance, and should begin as early as possible.

STEM education has roots at least as far back as the space race and launching of the satellite Sputnik, which sent America into a tailspin to keep up with the rest of world in the fields of mathematics, technology, and the sciences. Government officials have increased funding and control in order to encourage students to engage in STEM fields and hopefully choose STEM-related careers. The importance of STEM education can be seen not only in its importance to the American people, but also in its benefit to student learning. Inquiry-based education and learning through experience is supported through a STEM curriculum. This inquiry-based education and STEM focus is particularly important for younger students, as they are receptive to inquiry-based learning and can be hooked into STEM fields at an early age.

Problem Statement

Means et al. (2017) conducted a study looking at the effects of STEM-focused high schools on students' GPAs (grade point averages) and standardized test scores. These researchers found a positive correlation between this STEM-focused curriculum and test scores in math and science, along with overall GPA. A similar study by Saw (2019) looked at test scores in mathematics and science over the course of a ten-year period from students at a STEM-focused high school in Texas. Saw found completion of the STEM-focused program had no impact on the mathematics and science test scores for these students. When researching the impact of STEM-focused programs on academic achievement, one finds there is research on its impact at the secondary level, however, there is a gap when it comes to STEM and elementary achievement.

Considerable research exists on STEM-focused programs and their impact on underrepresented groups. Weis et al. (2015) looked at how STEM-inclusive high schools in two cities served to improve the achievement gap that impacts underrepresented groups. The results were inconclusive, showing no significant improvements in the academic achievement of these students involved.

Studies that include elementary school students and STEM education often look at students' perceptions of mathematics or science after experiencing STEM curriculum. Ching et al. (2019) researched the impact an after-school STEM program had on elementary students and their attitudes towards mathematics and science. Ching et al. found the program to have a positive impact on the students' perceptions of both mathematics and science.

English and King (2015) conducted a study that looked at the impact a fourth grade STEM unit had on the students' acquisition of the concepts. This study was qualitative and did not address students' success on any formal assessment. In order to support the worth of STEM-focused programs and curriculum, more research must be done to support academic growth at the elementary level. Sarican & Akgunduz (2018) cite the need for research into STEM education and its impact on academic achievement to be studied more in-depth, especially across levels of schooling including elementary school. Toma and Greca (2018) also noted the need for further research into STEM and academic achievement at the elementary level. The problem is that the literature has not fully addressed the impact of a STEM-focused education on elementary school math and science achievement.

Purpose Statement

The purpose of this quantitative, causal-comparative study is to examine the impact on the academic achievement of students in schools with STEM-focused programs or curriculum. Causal-comparative research seeks to discover a cause-and-effect relationship between the independent and dependent variables after an event has occurred (Gall et al., 2007). For causal-comparative research, the independent variable must be one that can be categorized and measured through defined categories (Gall et al., 2007). For this study, the first group spent their fifth-grade school year at schools determined to have a STEM-focused program, the second group did not. Criteria for determining which schools provide STEM-focused programs were used prior to choosing groups. The dependent variable was the students' test scores on the Virginia Standards of Learning (SOLs) Mathematics and Science Fifth Grade Assessments. This data was obtained from the Virginia Department of Education (VDOE), which publishes yearly score reports for each school and district in Virginia after completion of the SOLs (Virginia Department of Education, 2020). The local school district chosen for the study provided data for the study.

The population for this study was fifth grade students within a school district in Virginia. The sample for this study was contained to fifth-grade students attending four schools, Schools A, B, C, and D, within that district. For the categories, students who received a STEM-focused curriculum and those who did not, a minimum of 96 students were included in each. These schools can all be considered rural schools, with at least 40% economically disadvantaged (Virginia Department of Education, 2019).

Significance of the Study

Through studying the academic impact of STEM-focused programs at the elementary level, this research adds to the literature concerning STEM-focused schools and their impact on mathematics and science achievement. Master et al. (2017) studied the benefits gained by first-grade students who participated in a computer engineering program, which was considered to fall under STEM. These researchers aimed to look at the benefits to girls who participated in these STEM activities. The research showed that girls who participated in these programs had a higher motivation when it came to technology, including STEM-related activities. Early STEM-experiences were highlighted in this study, and these researchers indicated the need for more studies focusing on these early experiences. Through looking at STEM-focused programs in later elementary school, this study will add to the literature on these early STEM experiences and their possible benefit. With more research into these early experiences, more support for teachers and students alike could be provided in terms of STEM education.

Increasing exposure to STEM in elementary school becomes more important as our world demands more young people who have chosen STEM-related fields as careers. Massey (2018) highlighted a school district whose local business partner provided financial support and materials to the elementary schools to encourage students in STEM education. To further support this knowledge that STEM exposure should begin at a young age, Tran (2018) found elementary students who were exposed to STEM curriculum had a more positive view of STEM and encouraged them to choose STEM-related careers. In support of research highlighting the positive impact of STEM education in the elementary school, this study will add to the literature in terms of STEM education and its possible benefits to academic achievement.

Means et al. (2017) conducted a study concerning the impact of STEM-focused high schools on students' academic achievement. These researchers found a positive relationship between students who attended a STEM-inclusive high school and their test scores in mathematics. Means et al. also found a positive relationship between science test scores for those students in STEM-inclusive schools in one of the states included in the study. By conducting a study on academic achievement at the elementary level, the researcher will contribute to the literature surrounding these STEM-inclusive or STEM-focused schools. Through research into STEM-focused programs and their effect on student achievement, STEM funding and professional development for teachers can be bettered supported by educational stakeholders.

Acar et al. (2018) conducted a study concerning academic achievement of fourth-grade students whose teachers were trained in STEM practices. These researchers found a positive correlation between this training and students' academic achievement in mathematics and science. The current study will attempt to expand upon this research past teacher training programs to show how a STEM-focused curriculum could impact academic achievement for elementary students. This research could provide rationale for increased funding to STEM programs, increase training for teachers, and general support in this emerging field for students.

Research Questions

RQ: Is there a difference in fifth grade students' science and math achievement scores between students who experience STEM-focused curriculum and those who experienced a traditional math and science curriculum?

Definitions

1. *Academic proficiency* – Academic proficiency is measured by the Virginia Department of Education's (VDOE) Standards of Learning (SOL) assessments in both Grade 5 Science and Grade 5 Mathematics. According to the VDOE, academic proficiency is met by a score of 400 or higher on any SOL assessment, advanced proficiency is met with a score of 500 or higher, and 600 is a perfect score (Virginia Department of Education, 2020).
2. *Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science (America COMPETES) Act* – The America COMPETES Act put in place by President George Bush which pushed further research and implementation of STEM practices in schools. This act also gave funding for schools specializing in STEM-based practices (Thomas & Williams, 2009).

3. *Educate to Innovate* – Educate to Innovate was legislation created by President Barack Obama aimed at increasing the presence of STEM and associated practices throughout all levels of schooling over the following decade. This included the creation of 100,000 STEM teaching positions (Beilock & Maloney, 2015).
4. *Inquiry-based learning* – Based on the work of John Dewey, inquiry-based learning is characterized by hands-on exploration of the natural world in order to solve problems presented in a real-world context (Lazonder & Harmsen, 2016).
5. *National Defense Education Act (NDEA)* – The National Defense Education Act was legislation introduced by President Dwight D. Eisenhower in response to the launch of the first artificial satellite by the Soviet Union. This legislation was created to increase interest and attainment in the fields of science and technology (Clark, 2017).
6. *STEM* – STEM is an acronym created by the National Science Foundation to describe the integration of the fields of science, technology, engineering, and mathematics (Holmlund et al., 2018).
7. *STEM-focused schools* – STEM-focused schools are "Schools that focus in some way on science, technology, engineering, and math" (Eisenhart et al., 2015). This can include instructional strategies and programs targeted at STEM, staff members specifically dedicated to STEM instruction, and equipment or labs for STEM instruction.

CHAPTER TWO: LITERATURE REVIEW

Overview

The purpose of the following literature review is to evaluate the origins of STEM education, its connections to 21st century and hands-on learning, and the literature connected to STEM education and academic achievement. The literature review begins with an overview of the theoretical framework in which STEM education is based, including reference to John Dewey and inquiry-based learning, Bandura's social cognitive theory, and the benefits of problem-based, hands-on educational experiences. Also addressed are current definitions and terms relevant to STEM and STEM education. The related literature section addresses research that has been conducted concerning STEM education in secondary, post-secondary, and middle schools, underrepresented groups, and the smaller base of research available on STEM education at the elementary level. The chapter concludes with a brief summary of the evaluated literature.

Theoretical Framework

The emergence of STEM in education is a fairly recent addition to the educational scene, however, its roots lie in many forms of hands-on learning, inquiry-based learning, problem solving, and learning through social interaction. The following framework provides a theoretical background as a justification for STEM education, and concludes with a definition of STEM and STEM-related concepts.

John Dewey

While the acronym for STEM did not emerge until the 2000s, the basis for this type of education began much earlier. John Dewey believed that teachers should be the vessels for connecting students' prior knowledge to current learning situations through hands-on learning experiences (Doddington et al., 2018). His theories have influenced education in the past, and continue to do so today.

Dewey believed in and touted what is known as progressive education, which is education that is based in experience with subject matter that includes social interaction and age-appropriate activities (Dewey, 1938). Dewey thought education, as it had been previously presented to children, was not developmentally appropriate and was based in the learning styles and needs of adults, not children (Dewey, 1938). According to Dewey, classrooms should be places where students are given the opportunity to participate in education in a more interactive and social way (Dewey, 1938; Gutek, 2014). Dewey's beliefs are important to STEM education, as STEM education and STEM-focused programs are so deeply rooted in hands-on learning experiences with social interaction while solving meaningful problems (Shahali et al., 2018).

Dewey's Experimentalist Curriculum

John Dewey was a staunch believer in the scientific method, and his ideal curriculum would have been centered around such. In his experimentalist curriculum, students would use the scientific method to solve problems presented to them in a natural and meaningful way (Gutek, 2011). His approach to curriculum included students' using the scientific method as a means to solve problems and participate in their world, with emphasis placed on making meaning for them at the appropriate developmental level (Gutek, 2011). Subject areas would not be taught in an isolated fashion, but would be integrated and occur in a more natural manner. Dewey would have most likely been a proponent of the integration that STEM requires. Science would focus heavily on applying the traditional subject areas to solving problems presented to the learner within their social environment (Gutek, 2011). This experimentalist curriculum was one of the first that focused on the learner as the center of the classroom, with their interests and interactions as the guiding force in teaching. STEM education, in turn, has focused on an integrative approach that requires problem-solving in a real-world context (Julia & Antoli, 2019).

Dewey and Inquiry-Based Learning and Teaching

John Dewey was a science teacher who believed in the importance of learning through inquiry. He believed in the power of the scientific method; specifically forming a hypothesis, researching and collecting data, analyzing data, and presenting a conclusion (Barrow, 2006). Inquiry-based teaching and learning is also based in the scientific method, with student discovery at the center. In inquiry-based teaching, the teacher's role is changed from traditional teacher to more of a guide or facilitator of learning (Schunk, 2016). Instead of telling the answers or content, students are guided towards discovery of the answers themselves (Barrow, 2006). Students should be actively involved in their education, through the use of some form of the scientific method. Inquiry-based teaching and learning and the use of the scientific method are integral parts of an effective STEM integration (Psycharis, 2016).

John Dewey and Today's Education

While John Dewey's ideas are not wholly used in education today, portions can be seen enduring in current curriculum philosophies. Schiro (2013) stated schools should be places where learners are actively involved in both choosing their learning and carrying it out. This is considered learner-centered ideology. Schiro is quick to note the importance of context, particularly for young learners, as it is so important for them in making meaning of their learning. Subjects should not be taught separately, but rather in an integrated fashion within the students' school day. This type of learning and teaching lends itself well to STEM, as methods of delivering STEM instruction are centered around active engagement, student choice, and use of inquiry-based teaching and learning (Cavanagh et al., 2016).

Bandura's Social Learning Theory

Albert Bandura, an educational philosopher with beliefs rooted in behaviorist learning theories, brought to the educational scene his social learning theory, or social cognitive theory (Schunk, 2016). This theory states that people, not only children, learn from their social interactions and settings (Schunk, 2016). Bandura believed that learning occurs when the learner socially interacts with their environment, and those in their environment. This might include listening to or watching a teacher model instruction, working with peers, actively using learning materials, or in some way engaging with the content (Schunk, 2016). Further, Bandura supported self-guided learning, which involves interests and actions from the learner (Bandura, 1971). Bandura's theory of social learning maintains that learning occurs best when students are actively engaged in both the environments and those within the environment (Schunk, 2016).

Within Bandura's social learning theory, he posits that learning occurs when students are confronted with novel situations for which they must come to a solution (1971). Through this direct experience students try different problem-solving techniques, some that work and some that do not. By using trial and error, students learn how best to navigate the problem, essentially a system of rewards for what works, and consequences for what does not (Bandura, 1971). STEM education often consists of an inquiry-based approach to solving problems, requires students to research problems and troubleshoot various solutions, then present their findings (Sahin & Top, 2015). At the heart of STEM education is an insistence that students use resources, human and otherwise, to learn content in a way that supports the social learning theory.

Facilitative Learning Theory

Working hand-in-hand with Bandura's social learning theory is facilitative learning theory. In this, the teacher becomes more of a facilitator in the learning, rather than assuming the traditional role of the purveyor of knowledge (Sahin, 2013). Facilitative learning, which is a student-centered approach to delivering content, has been shown to heighten the effectiveness of creativity in students' science academics (Hardika et al., 2018, & Sahin, 2013). STEM learning situations are best suited for student-centered instruction and facilitative learning models.

Hands-on Learning and Problem-Based Learning

STEM education provides the opportunity for hands-on learning experiences. Approaches to teaching that integrate subject areas, such as STEM education, provide students with the opportunity to define problems, work towards solutions using various means, and incorporate hard-to-teach skills like engineering and design (Kelley & Knowles, 2016). Integrating STEM education has been shown to improve students' learning with both mathematics and science (Fan & Yu, 2017).

English (2016) cites STEM education as a problem-based learning (PBL) approach that includes active teaching and learning through students' exploration of the subject matter. Learning science through hands-on exploration with scientific tools and integration of subject matter has been shown to help students retain scientific content knowledge (Jones & Stapleton, 2017). Much discussion has occurred over the last ten years about the benefits of authentic learning experiences. DeChambeau and Ramlo (2017) cite the ease with which STEM has been integrated into PBL models. These PBL experiences, when integrated with STEM, provide students with an authentic learning experience. Moreover, these PBL with STEM experiences have been shown to increase student engagement in the classroom, foster an improved attitude towards learning, and a decrease in course dropouts (Han et al., 2015).

Since the 1950s, there has been an increased focused on student-centered learning that enables students to become problem-solvers ready for a world with a growing need for engineering jobs (Saito et al., 2016). Connell et al. (2017) list student-centered learning, where students are actively engaged in the learning, as preferable over traditional lecture techniques. These active learning strategies provide students with a deeper learning experience and have been shown to heighten academic gains for students. Students enrolled in higher-level sciences, such as college Physics, have been shown to benefit from a student-centered learning approach, and gain a deeper understanding of the subject matter (De Jong, 2019).

21st Century Skills

Within the last ten years, 21st century skills have emerged as a need in the American workforce, and in turn, in American education (Husin et al., 2016). 21st century skills, or 21st century competencies, are those skills which have been recently pointed out as necessary to the emerging workforce, in order to meet the demands of the rapidly changing 21st century (Oudeweetering & Voogt, 2018). These 21st century skills involve digital competency skills, communication skills, critical thinking, inventive and creative thinking, and other proficiencies necessary for students of this age to have when entering to workforce (Husin et al., 2016). Educational researchers and practitioners continue to examine how to address the needs for students' acquisition of 21st century skills, and this examination has led many to a STEM-focused education (Jang, 2016).

STEM activities and curriculums have been found to improve critical thinking skills, problem solving skills, and creativity (Kubat & Guray, 2018). Critical thinking can be defined as, “the ability to transfer these skills outside of the classroom into ‘real-world’ settings” (Pearl et al., 2019, p. 117). With problems in today’s world that are technologically advanced and globally significant, critical thinking skills are necessary for creating solutions to these. Being able to think critically and plan solutions to these problems is essential to employers and to our future (Fan & Yu, 2017). Global problems concerning health, energy, and the environment could be solved or at least worked on through the use of STEM concepts taught in school (Kelley & Knowles, 2016).

Creativity works hand-in-hand with critical-thinking and problem-solving skills. While previous thought was creativity was a broad skill, it is now considered a field-specific skill. In science, creativity is necessary in order to make new discoveries and create new products (Ugras, 2018). STEM education and practices inherently encourage creativity because of the focus on the process, rather than the product (Guo & Woulfin, 2015).

Social Identity Theory

Concerns about equity for all students is at the forefront of education, particularly in our rapidly evolving world (Cochran-Smith et al., 2016). Social identity theory is the theory that stereotypes defined by society may in fact have a negative impact on underrepresented groups (Rattan et al., 2018). Kang and Kaplan (2018) cite underrepresented groups as having been just such in STEM fields as well, particularly women of color. Kang and Kaplan stated this lack of representation in STEM fields could be related to social identity theory, in that these groups may not feel as though they can be part of the STEM community. Lisberg and Woods (2018) indicate better academic outcomes when students, especially those underrepresented groups, have early experiences with active, hands-on learning, like experiences with STEM in education.

Lynch et al. (2017) cite the potential of STEM education as a possible catalyst for engaging underrepresented groups in deeper learning experiences and ultimately contributing to greater academic success for them. This could also lead to persistence in pursuits of higher degrees in STEM and more underrepresented groups in STEM careers. Lynch et al. further cite the possibility of an early STEM education as being an avenue towards bridging the gap that exists in equity for these groups of students.

Situated Cognition Theory

Situated cognition theory is another theory of importance to the study of STEM education. This theory states learners are most productive in their learning when situated within a context where application of concepts learned is required (Kelley & Knowles, 2016). The theory further suggests learners actually achieve the highest level of cognition when immersed within a real-life situation where concepts learned could be applied, especially where scientific processes are concerned (Zhu et al., 2019). Brown et al. (1989) cite the importance of keeping a social context relevant to the learner, along with a physical context if possible. These researchers touted the significance of apprenticeships in job training, but this can also be applied to STEM education. If one of the goals of STEM education is to prepare students for their future working world, then STEM education can be thought of as working in what will eventually be their real social and physical context.

An Overview of STEM Education

The origins of STEM education lie in many theories of active learning, and are well-supported by educational voices of the past. A clear and concise definition of STEM education still is not agreed upon today (English, 2016; Kelley & Knowles, 2016; & Xie et al., 2015). The quest for this definition has been a topic of discussion since the introduction of the acronym STEM in the early 2000s (McComas & Burgin, 2020), and continues to lack a definitive answer.

At the elementary level, STEM education has been thought to overwhelmingly focus on the subjects of mathematics and science, as these are a part of the core of subjects in traditional elementary schools (Xie et al., 2015). STEM education at this level might be looked at as merely a science activity that involves mathematics, all the way to an integration of science and mathematics into a problem-solving context requiring engineering skills or use of technology (English, 2017). At the secondary level, STEM education can vary even more widely than at the elementary level. STEM education can be seen within the core curriculum of mathematics and sciences, through students' chosen electives (Xie et al., 2015), outreach programs designed to engage students in STEM practices and education (Barrett et al., 2014), to schools that are designed with STEM integration as their primary mission (Saw, 2019).

Levels of STEM Integration

Integration of STEM education does not happen at the same level, even within the same age groups. Vasquez et al. (2013) offered a four-tiered model to explain the level of STEM implementation within a classroom or school. Disciplinary integration would include integration within each of the subject areas, but not an integration among subject areas. This approach is looked at as a way to strengthen academic proficiency and understanding in particular subject areas, such as mathematics or science, and is often called a siloed approach to STEM integration (Vasquez et al., 2013). The multi-disciplinary approach still requires the teaching of separate subjects, but would integrate STEM education into those subjects under the umbrella of a similar theme (Leung, 2020). The inter-disciplinary approach to STEM education involves using STEM in an integrated fashion in at least two subject areas (Kelley & Knowles, 2016). This differs from multi-disciplinary in that the work between the at least two subjects would be almost totally dependent on the other. Finally, the transdisciplinary approach involves problem-based or project-based learning situations where students are asked to apply their STEM skills, within many disciplines, to a larger project (Leung, 2020). While the transdisciplinary approach would seem to be the most integrated, all approaches can be considered STEM in education. Within all of these approaches to STEM integration, it is generally agreed that all parts of the STEM acronym (science, technology, engineering, and mathematics) do not need to be addressed during each learning experience or lesson in order to qualify as STEM education (Kloser et al., 2018).

One term that has recently emerged in the quest to define STEM education is the term iSTEM (McComas & Burgin, 2020, Reynante et al., 2020, Schuchardt & Schunn, 2015, & Thibaut et al., 2019), which refers to the integration of science, technology, engineering, and mathematics (iSTEM). This approach requires teachers to incorporate at least two of the STEM subjects into teaching concepts that require use of real application or problem-solving skills (Reynante et al., 2020). Often, in order to integrate the content areas, design challenges or engineering challenges are presented to students (Thibaut et al., 2019), and require the use of science and mathematics, thereby incorporating multiple portions of STEM. Schuchardt and Schunn conducted a study involving an iSTEM approach to teaching higher level mathematical concepts to secondary students. These researchers found, when applying iSTEM, students showed a greater ability to understand the math concepts and were further able to solve complex math equations. Thibaut et al. also cite increased motivation and interest in STEM education from iSTEM education. Reynante et al. reference increased motivation, greater understanding of new concepts, and an improved ability to learn new concepts within each of STEM's disciplines when an iSTEM approach is implemented. Bybee (2013), however, cautions educators to remember STEM learning and education does not have to come in this exact package to be effective and beneficial to students. Rather, approaches to STEM education, and even iSTEM education, vary widely.

A Definition

To define STEM education, we must include more than a single sentence, and further look at STEM education through the lens of goals and practices. One of the accepted main goals of STEM education is that students involved in STEM education should acquire a set of STEM literacy skills (English, 2016, & Leung, 2020). STEM literacy skills, "include research inquiry, problem solving, critical and creative thinking, entrepreneurship, collaboration, teamwork and communication" (Falloon et al., 2020, p. 369). Generally, it is also accepted that approaches to STEM education must include a problem to be solved (Kloser et al., 2018). This problem might be very subject-specific, or might be situated within a context relevant to the student. Along these same lines, scientific inquiry in pursuit of answers to these problems is another key element in STEM education (Holmlund et al., 2018, & Kelley & Knowles, 2016). Although no definition reaches all areas of STEM or perfectly describes STEM integration in the classroom, Sanders (2009) created a substantial definition: "STEM education includes approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects" (p. 21).

Related Literature

STEM education has become a hot topic in the educational community, as the need for students to choose STEM-related careers increases each day (Kelley & Knowles, 2016). Faculty, staff, and administration of schools have seen the increased demand for this type of education. The demand for STEM education has required educators to think past the single subject approach, delve into inquiry-based learning, present problems in context to students, and increase rigor in the curriculum (Kennedy & Odell, 2014). With the increased need for STEM-literate graduates and the changing school curriculum, research must be conducted to examine the importance and effectiveness of STEM education.

STEM Pipeline

The STEM pipeline is a term that comes up often when addressing STEM education. This term has roots far further back than STEM itself, originating in the idea of the need for more of the workforce to choose careers in the sciences (Allen-Ramdial & Campbell, 2014). The term pipeline could be heard as early as the 1970s, when the world began to realize the need for individuals to fill scientific and technological jobs (Mendick et al., 2017). According to this idea, success is measured by how many people end up choosing careers in science, or continue with post-graduate education in the sciences. From this emerged the term STEM pipeline, with the same parameters. The STEM pipeline begins early, how early is constantly up for debate and further research, with the pipeline consisting of smaller and smaller numbers of individuals choosing STEM-related paths along the way (Cannady et al., 2014). This path or pipeline includes, from the beginning to end, choosing STEM coursework in high school, the selection of STEM major in college, retention to graduation in STEM majors, and finally funneling out into a STEM careers or post-graduate STEM coursework and higher degrees.

The suggestion is perhaps the STEM pipeline is “leaking,” which refers to the loss of individuals involved in STEM through said pipeline from early coursework and experiences to college graduation and career choice (van den Hurk et al., 2019). This so-called leakage has been the subject of much recent research (Bergeron & Gordon, 2017, Le & Robbins, 2016, Redmond-Sanogo et al., 2016, & van den Hurk et al., 2019). Le and Robbins followed students from middle school through college to track which students were successful in their STEM tracks and factors that may have contributed to this success. Bergeron and Gordon addressed the loss of females in higher level STEM courses, despite equal performance to their male counterparts. All of this research contributes to the growing concern for attracting and retaining individuals who will ultimately choose college majors and careers in STEM fields.

Criticisms of STEM Education

Like any educational topic worthy of discussion, STEM education has its criticisms and critics. Some believe the ambiguity of the term STEM and its relation to education is a problem (McComas & Burgin, 2020, & Sanders, 2009), as this allows for too wide a range of instructional implementation to be classified in the same realm. Some believe STEM education must involve the full integration of all parts of STEM, with no separate or siloed subjects, while some believe any integration of the parts constitutes STEM education (Hallstrom & Schonborn, 2019). This lack of a clear understanding has led to arguments from both sides, and thus criticism of practices from one side to the other.

Another criticism of STEM education has come in the form of teacher training. Often cited is the lack of teachers who are properly trained in any of the STEM disciplines, much less in STEM implementation in the classroom (Nesmith & Cooper, 2019, & Sanders, 2009). Professional development in the practice of STEM education is one answer to this criticism, however, current trainings may not yet be well-developed enough to give teachers the necessary skills and support in this endeavor (Du et al., 2019). Wu et al. (2019) suggest teacher training should be aimed more at developing teachers’ skills in creating an experiential learning environment for students, rather than traditional approaches to professional development that tend to center around helping students acquire knowledge and skills.

Yet another criticism of STEM education is the leaking of the STEM pipeline, especially in reference to underrepresented groups (Atkins et al., 2020, Estrada et al., 2016, & Lee, 2020). Atkins et al. cites the lack of representation of minority students and females in STEM education at both the undergraduate and graduate levels. The loss of these students' choice of STEM-related fields begins at the secondary level and continues to increase along with the progression of schooling (Estrada et al., 2016). Lee recognizes students with disabilities (SWD) as being another group who are not adequately served by our STEM education agenda in the US.

STEM Education and Teacher Training

With the ever-increasing educational buzz surrounding STEM education comes the need for teachers who are STEM trained. This need has even been covered in government documents such as the executive report from the President's Council of Advisors on Science and Technology (2010), which called for the need to "recruit and train 100,000 great STEM teachers over the next decade who are able to prepare and inspire students" (p. 12). Much research recently has been geared towards understanding what makes teachers want to specialize in STEM education, and how better to draw teachers into the field (Affouneh et al., 2020, Hubbard et al., 2015, Scaradozzi et al., 2019, Wu et al., 2019, & Yip, 2020).

Wu et al. (2019) cited the need for more STEM teachers and conducted research regarding the importance that this commitment begin with pre-service teacher training. These researchers found scaffolding during STEM training, especially with pre-service teachers, to benefit teachers' learning and further qualify them to conduct meaningful STEM learning experiences for future students. Yip (2020) similarly looked at pre-service teachers' STEM training through the lens of their enrollment in a STEM course, which allowed these future teachers to engage in STEM activities as the students would. Yip found these pre-service teachers felt more capable of teaching the STEM content, better understood how to deliver effective STEM instruction, and allowed them to feel more comfortable with planning STEM instruction. Hubbard et al. (2015) examined programs aimed at attaining and retaining STEM teachers from the pre-service level.

In-service teachers' involvement in STEM education is likewise important to the current research on STEM education and teachers. Affouneh et al. (2020) looked at factors that possibly impact teachers' willingness to participate in STEM professional development, their feelings on its effectiveness, and their attitudes towards STEM training. Their findings were varied based on personal experiences, other training, and knowledge or skills in STEM, however, Affouneh et al. cite their research as beneficial to those planning professional development in STEM for in-service teachers. Wang et al. (2011) also addressed in-service teachers' perceptions of STEM education, professional development concerning STEM, and how this impacted their implementation of it in the classroom. Wang et al. found teachers to be likely to implement STEM practices when they felt they had adequate knowledge and that classroom practices may vary according to teachers' training levels and beliefs about STEM overall. Scaradozzi et al. (2019) conducted a study looking at the impact of a STEM training on in-service teachers' knowledge of the STEM practice and confidence in using the material from the training. Scaradozzi et al. found both teachers' knowledge of the STEM practice and confidence in implementation of it to improve after the training.

STEM Education and Mathematics

One portion of the STEM acronym is mathematics, which is of particular concern to this study. Maass et al. (2019) recognize math as an essential part of all STEM fields, however, it is often forgotten in STEM education, with science taking priority. Li and Schoenfeld (2019) point out the importance of student discovery and meaning-making in mathematics, and how well STEM education goes hand-in-hand with this sort of learning. They suggest perhaps when teachers delve into mathematical concepts with students, employing the STEM strategies of creativity and design might provide deeper learning in math. Maass et al. also point out the connection between 21st century skills, mathematics education, and STEM. Employers consistently cite the need for 21st century skills in their employees, and mathematics encourages the acquisition of these skills (Maass et al., 2019).

The importance of mathematics in students' future STEM endeavors is the subject of much current research (Bottia et al., 2015, Delaney & Devereux, 2020, & Lin et al., 2018). Lin et al. (2018) found math self-efficacy to be linked to whether or not students chose STEM majors in college. In their study, Lin et al. found students who were perceived to have lower self-efficacy in mathematics were less likely to choose STEM majors or less likely to continue in STEM majors to graduation. Delaney and Devereux found students with higher mathematical abilities more likely to choose STEM majors and persevere in the first STEM-related classes as undergraduates. Not only did these students perform better academically in those courses, but were also more likely to obtain STEM degrees. Lin et al. suggested this link between mathematical ability and self-efficacy may begin as early as elementary school. Bottia et al. also found exposure to mathematics in high school and high school mathematics teachers to have an impact on both choice of STEM major and graduating with a STEM degree. Clearly, math is a significant factor in success for STEM education.

English (2016) offers various avenues for strengthening the math portion of STEM education. First, mathematics could be presented within STEM education as the focus of lessons or units, rather than a supplement to the STEM unit. Often, in the past, math is merely a skill included in the STEM focus, rather than the primary objective being taught. Also, educators need to place attention on the emergence of data and data analysis as it relates to our online and changing world. Students are increasingly required to make decisions and judgements based on data presented to them, so it follows that STEM education could address the proper way to do this. Last, English proposes mathematical literacy as an avenue to highlighting the mathematical part of STEM. This includes students' ability to work with math in real-life situations, and apply those concepts in meaningful ways.

STEM Education and Science

The first letter in the STEM acronym stands for science, and there is no denying its importance to STEM fields and education. Dou et al. (2019) list experiences, formal or informal, with science in the early years as a link to later choice of college major and career in STEM. STEM in the science class, and moreover, the integration of technology, math, and engineering into science as a subject, is coming to be seen as an excellent way to approach the teaching of science (Park et al., 2020). Habig et al. (2020) found participation in science experiences to increase the likelihood of choosing STEM majors and careers, including an increase in underrepresented groups for both of those categories.

The *Next Generation Science Standards (NGSS)* (NGSS Lead States, 2013) have been developed as a national set of science standards, having a focus on understanding and applying scientific concepts, rather than rote memorization (Dare et al., 2019). These standards call for the integration of STEM in their very nature, as they ask teachers to take a less lecture-based approach to teaching science, and to branch out into a more inquiry-based, hands-on style of science education. In fact, the NGSS standards specifically address the integration of engineering design, mathematics, and literacy into science instruction (Bybee, 2014). As can be clearly seen, one cannot look at STEM education without also looking at science education.

STEM Education at the Post-Secondary Level

STEM education at the collegiate level is an important portion of the research on STEM education. STEM education in college has been looked at in research due to the increased demand for students to choose STEM-related majors, to in turn enter the workforce in STEM fields, possessing the skills necessary to be successful in these STEM-related fields (Carlisle & Weaver, 2018, English, 2016, & Kelley & Knowles, 2016). Of interest to researchers is finding out what makes students choose these majors, and what makes them continue in those programs through graduation. Wu et al. (2018) looked at college students' self-efficacy in mathematics (in relation to courses necessary for a STEM major) specifically throughout the duration of a Calculus course. One version of the course was taught using a more traditional, non-engineering format, and the other version employed an engineering, technology-focused style. Researchers found students who participated in the engineering-focused Calculus course showed heightened enjoyment of mathematics, belief in their mathematical ability, and the desire to take more courses in mathematics. Persistence in mathematics is necessary in completion of STEM degrees.

Hecht et al. (2019) examined the effect of a utility-value inventory (UVI) implemented during beginning science courses for students enrolled as STEM majors. The UVI consisted of writing assignments where students were asked to address their feelings on the relevance and value of the courses they had taken. Researchers chose to look at the effects two years after initial implementation of the UVI, and whether this had any impact on these students persisting in their STEM major, as opposed to those who did not participate in the UVI. The results did not show a direct impact on STEM persistence from the UVI, but did show an impact from the UVI in terms of academic performance in those courses.

Also important to the research in STEM education at the collegiate level are studies concerning underrepresented groups in STEM majors. Crisp et al. (2009) studied the choice and persistence rates of students choosing a STEM major at a Hispanic Serving Institution (HSI). These researchers found high school GPA, courses taken in early college, gender, and ethnicity to have an influence on students' choice in STEM major and completion of a STEM-related degree. Alvarado and Muniz (2018) sought to examine the effect of early STEM interventions on choices of major in college and career afterward. They found these early interventions to have a correlation for African American students' choice in career and major, but not for Latino and Asian students.

STEM Education and Secondary Schools

Much research has been conducted on STEM education, and STEM-focused programs in secondary schools. Christensen et al. (2015) looked at the impact STEM education and STEM-focused activities had on middle and high school students' STEM dispositions. These researchers found students who engaged in STEM-related activities, or were immersed in a STEM education program, were more likely to choose college majors related to STEM and more likely to have a positive outlook on STEM education. Likewise, Vennix et al. (2018) obtained mixed results from a study that examined how outreach STEM activities affected secondary students' perceptions of STEM education and whether these STEM activities had an impact on their decision to choose a STEM-related major or career path.

Academic Achievement and STEM Education in Secondary Schools

Like attitudes towards STEM education, secondary students' academic achievement in STEM-focused programs and schools have also been addressed in the literature. Means et al. (2016) found students of STEM-focused high schools in North Carolina to have higher grade point averages (GPAs) and better attendance records than those of non-STEM-focused high schools. Similarly, Crotty et al. (2017) found students who experienced a unit of study with a focused STEM integration made academic gains, particularly in the area of engineering. Fan and Yu (2017) had similar findings in their study of the impact of a STEM-focused curriculum on a unit of study in a high school in Taiwan.

Texas STEM academies were examined for their academic impact on high school course grades and GPAs, with the finding that these STEM-focused programs did not seem to have a significant impact on academic achievement (Saw, 2019). In a similar study, Bicer and Capraro (2019) looked specifically at the math achievement of those students enrolled in Texas STEM-focused academies compared to those enrolled in traditional high schools. These researchers also found no overall significant difference in the mathematics assessment scores between the groups of students.

Consideration has been given in research to STEM education being an asset to secondary programs in terms of improving standardized score outcomes. Thomas et al. (2016) looked at the impact of a STEM-focused tutoring program on the standardized test scores of students in an urban school district. These researchers found the tutoring program, designed to boost scores in areas related to STEM, to have a positive impact on Biology scores, but not on Algebra scores for the first group involved in implementation. However, when looking at the second year's group in Algebra, passing scores did increase for those students.

Patel et al. (2019) also chose to look at the influence of STEM education on academic achievement at the secondary level. These researchers compared four types of high schools; each including a varying level of STEM implementation. Overall, they did not find statistically significant differences between the levels of implementation, but did find increased academic achievement from high schools with some form of STEM implementation, rather than a traditional curriculum approach only.

The effects of STEM-focused curriculum in vocational education at the secondary level was examined by Cevik (2018). Cevik found students enrolled in a vocational furniture design course made significant academic gains when a STEM-focused curriculum was used with them. Similarly, Nurtanto et al. (2020) found students in an automotive engineering vocational course curriculum made academic gains when STEM practices were employed in the teaching of the course.

As mentioned above, problem-based learning (PBL) and STEM education have been linked in educational settings, as the two tend to go hand-in-hand. Craig and Marshall (2019) conducted a study aimed at examining the impact of PBL on the mathematics standardized test scores of secondary students. These researchers looked at the mathematics scores of students enrolled in a STEM-focused academy, comparing them using groups of students who received instruction using PBL and those who did not. While this is not a study directly addressing a STEM versus non-STEM focused education, it does address PBL as an element of STEM education. Students who received the STEM-focused education with the addition of PBL scored consistent with students who did not receive PBL instruction in every grade level at the secondary level except for tenth grade. The students in tenth grade who received PBL instruction scored higher on the mathematics assessment in tenth grade.

In a study similar to Craig and Marshall (2019), Morrison et al. (2015) looked at standardized test scores from students who attended a STEM-focused school with a mission to provide PBL experiences for their students. This school was compared to three local school districts and average state scores across standardized tests given in Algebra and Geometry. The STEM-focused school scored significantly higher in all four scenarios of comparison.

STEM Education and Middle Schools

Middle school students' perceptions of STEM education have also been examined through studies like that of Ozcan and Koca (2019), who looked at 7th grade students' perceptions of STEM education after receiving STEM-focused instruction. These researchers used a mixed-methods study to examine not only the students' attitudes towards STEM, and in particular the scientific content "pressure," but also looked at the effect on their academic achievement in that unit of study. Ozcan and Koca found a significant difference for the attitudes towards STEM and the academic achievement between the control and experimental group, with the experimental group scoring higher on both. Baran et al. (2019) conducted a study concerning the impact of an after-school STEM program on the STEM attitudes of sixth-grade students. These researchers found, through pre- and post-testing, attitudes toward STEM as a career, STEM learning, and knowledge of STEM concepts increased after implementation of the after-school program. In contrast, Lin et al. (2019) found no significant impact on students' attitudes towards STEM by the integration of a particular STEM-focused project in a middle school science class.

Research has been conducted on the impact of STEM education on middle school students' academic achievement. Kurt and Benzer (2020) compared two groups of middle school students, one who received traditional science instruction, and one group taught with STEM practices. These researchers found, using pre- and post-testing, the group taught with STEM practices to have higher scores than the control group. Similarly, Guzey et al. (2016) looked at the impact of teaching science units with STEM practices on content assessments given to middle school students. Guzey et al. found these practices to have a positive impact on student learning within these units. Sondergeld et al. (2020) examined the academic achievement of sixth- through eighth-grade students enrolled in a district focused on STEM initiatives and offering extra-curricular STEM enrichments. These researchers compared the students' overall, math, and science grades to those students' grades of a matched school district without STEM initiatives. They found the STEM-focused district's scores to increase, rather than decrease like the non-STEM district, and to have overall higher scores in those categories.

STEM Education and Underrepresented Groups

Along with an increased focus on encouraging participation in STEM-related career fields and college majors for all students, the need for boosting participation of underrepresented minority groups in STEM fields has also been called to the forefront of the educational scene (Estrada et al., 2016). There is a particular concern for this at the collegiate level, as underrepresented groups do not hold an equitable portion of the degrees being earned in STEM-related fields at the undergraduate or graduate levels (Xu et al., 2020). Atkins et al. (2020) cites underrepresented minority groups and females as being disproportionately represented in STEM degrees being earned at both levels of post-secondary education. Likewise, Espinosa (2011) chose to look at factors that could affect the retention rates of women of color in STEM majors in college and persistence to degree completion. Espinosa found factors such as peer groups, class discussions, extracurricular activities, and the size of the college to have an impact on whether women of color persisted in STEM majors from their freshmen years of college through graduation.

Researchers have looked at many avenues to increasing underrepresented groups' participation in STEM-related college majors and careers. Farinde et al. (2014) offered service learning projects and community involvement with engineering activities as a way to encourage underrepresented groups to establish an interest in and positive attitude towards STEM. Russell (2017) researched the use of learning communities among college freshmen as an avenue to encourage success in STEM among underrepresented minority groups and females. Toven-Lindsey et al. (2015) found success with an academic support program aimed at keeping underrepresented groups in the STEM-focused majors and earning degrees in STEM fields. Similar findings by Chang et al. (2014) support the need for institutional supports for underrepresented groups to maintain their track to graduation in STEM-related fields.

STEM Education and Students with Disabilities

Another underrepresented group in STEM majors and STEM-related careers are students with disabilities (SWD). Lee (2020) cites 13% of the population as having some form of disability, but are not likewise represented in STEM fields. Wells and Kommers (2020) discuss SWD as being less likely to choose a STEM-related major or complete a STEM-related degree. These researchers suggest SWD may feel less welcome in these fields, or may not feel supported by the academic institution.

In reaction to this need for more representation in STEM-related careers and college majors by SWD, many intermediate and secondary schools have started to offer programs aimed at promoting SWDs' interest in STEM. Lam et al. (2008) examined the impact of a STEM-focused program implemented at a middle school, which focused on including and encouraging students with Individualized Education Plans (IEPs) towards STEM fields and interests. These researchers found SWD, when given proper supports and modifications, showed increased interest in STEM-related classes and fields. In a similar study, Heinrich et al. (2016) found when SWD at a high school were given specific STEM instruction using specially designed modifications, not only were the SWD more successful, but so were general education students. Similarly, Plasman and Gottfried (2018) found SWD were more likely to finish high school, attend college, and increase math test scores after participating in STEM coursework. On the contrary, Gottfried et al. (2014) did not find STEM coursework or experiences to contribute significantly to SWD's choice in college major or persistence in STEM.

People with Autism Spectrum Disorder (ASD) are considered to be part of a disability group, and this group generally has a higher representation in STEM fields (Wei et al., 2017). Wei et al. looked at factors that could possibly contribute to people with ASD choosing STEM majors in college. These researchers found high school mathematics choices and scores were often a predictor of STEM choice in later years. Wei et al. encourage educators to include SWD in the regular classroom and offer higher level mathematics and STEM experiences to them in order to encourage their choice of STEM fields.

In order to better serve SWD, some researchers have posited the use of the arts in STEM education as an avenue to support SWD who may respond better with the incorporation of graphics and the arts (Hwang & Taylor, 2016). The term STEAM includes the integration of the word art into the acronym of STEM. In order for curriculum to be considered STEAM-related, art integrations, liberal arts, or forms of communication and creativity must be incorporated into the STEM curriculum (MacDonald et al., 2019).

STEM Education and Females

Currently, there exists a body of research looking at the participation and success of females in STEM education. Jungert et al. (2019) state that overall males are more likely to pursue college majors and careers in STEM than their female counterparts. This participation varies by country, by the particular field of STEM, and other factors, however, this discrepancy consistently exists where STEM is concerned. Casad et al. (2019) suggest this discrepancy could be due to the fact that women, especially at the undergraduate and graduate levels, do not feel secure in choosing STEM-related majors. Through their study, these researchers found this feeling of unwelcome could be due to a lack of female role models in STEM, or women may feel threatened by the educational environment offered at their institution.

Vincent-Ruz and Schunn (2017) also looked to describe the reason for the discrepancy between male and female representation in STEM fields. These researchers looked at beliefs of self-efficacy in both males and females in middle school relating to STEM classes and activities. They found males had higher self-efficacy towards science and STEM over the course of middle school, and they were more likely to participate in STEM-related activities and choose STEM courses. Females, on the other hand, showed lower self-efficacy over the course of middle school, which in turn made them less likely to choose STEM.

Another study to support a lower self-efficacy in females with STEM education from Ellis et al. (2016) looked at feelings of confidence in males versus females enrolled in a Calculus course. These researchers addressed the greater likelihood for females to leave STEM majors than their male counterparts. Ellis et al. compared male and female students of above-average mathematical intelligence, looking at their mathematical confidence levels at the beginning and the end of the course. They found a lower confidence level at both points, leading to a possible greater likelihood for females to leave STEM majors. Yet another study from Ertl et al. (2017) found the gender gap in STEM educational courses to likely be from a lack of confidence in this area, or a lack of support from people within females' lives.

STEM in Elementary School

For the current study, the researcher wishes to address the impact of a STEM-focused curriculum on fifth-grade standardized test scores. Research on STEM in elementary school has certainly increased in the last ten years, however, the elementary portion of K-12 education definitely has the least focus of all levels of education.

STEM Education at the Elementary Level

Relatively new to the research scene, STEM education in elementary schools has become a notable topic. Lesseig et al. (2019) cite problems with STEM integration at the elementary level due to the need for elementary teachers to be trained in math, science, and the implementation of engineering and design concepts, while also being trained elementary teachers. Lesseig et al. point out secondary teachers' training often includes one or more of these areas, therefore leading to an easier transition to incorporating these concepts into instruction. Elementary teachers may not feel prepared or ready to present instruction in STEM education, whether it be due to lack of formal training or other factors (Nesmith & Cooper, 2019).

Research is beginning to emerge concerning the benefit of STEM education at the elementary level, and what this might mean moving forward. Parker et al. (2015) conducted a study within a school district whose rates on almost all of their standardized tests were not meeting competency at the state level. Parker et al. looked at implementation of a STEM program at the elementary level aimed at raising those standardized test scores in math and science. This was a qualitative study, and results obtained from interviews and questionnaires were not intended to demonstrate academic improvement. The results did reveal the importance to teachers of high-quality professional development in STEM, the significance of having a STEM instructional coach available, and ultimately the benefit to the students that the teachers felt was gained through the program.

The National Research Council published a report in 2014 which described STEM education as experiences, as opposed to single lessons, which “may occur in one or several class periods, or throughout a curriculum; they may be reflected in the organization of a single course or an entire school, or they may be presented in an after or out-of-school activity” (p. 39). This broad definition addresses elementary school STEM integration well, as it is not yet clearly defined in the research like secondary integration is (Lesseig et al., 2019). Whether STEM integration be a whole-school approach, subject-specific, or an after-school activity, all are included under the umbrella of STEM education at the elementary level.

STEM Interest and Elementary Students

Researchers have begun to consider the importance of elementary students’ interest in STEM education, and started to look at how this might increase later interest in STEM fields. Sullivan and Bers (2019) looked at how an after-school robotics program, with a STEM focus, impacted elementary students’ interest in STEM education. These researchers closely examined the impact on females, in particular, and found the robotics program to have positive effects on these students’ interest in STEM education. In a similar study from Sullivan and Bers (2015) the effectiveness of a robotics program in kindergarten through second grade classes was examined. Results of this study indicated students were successful with STEM concepts by the end of the unit.

A case study from Graves et al. (2016) addressed STEM interest in elementary students during an interactive STEM unit involving a garden. In this study, teachers felt student interest was heightened by the STEM project, but did not feel this type of STEM activity supported student learning of the content matter. The teachers seemed to feel this project was more beneficial to students as an enrichment.

In a large study of 1,484 elementary age students, Babarovic et al. (2018) used surveys to assess the students' interest in STEM and attitudes towards STEM and scientific careers before and after implementation of a STEM intervention. Babarovic et al. found students' attitudes towards STEM were increased slightly after the STEM intervention, along with a slight increase in their interest in a STEM-related career.

Koul et al. (2018) assessed students' interests in STEM before and after implementation of engineering and technology lessons with students in grades 4-7. While this includes middle school students, the data from the students in 4th and 5th grades is of interest in terms of the current study. Koul et al. found a statistically significant change in the students' interest levels from before the engineering and technology lessons to after completion of the unit. The research overall seems to point towards increased STEM interest and interest in science in general from implementation of STEM-focused programs and units of study.

STEM in Elementary School and Academic Achievement

Of the most interest to this study is the research available concerning STEM implementation and academic achievement at the elementary level. Research exists concerning academic achievement with STEM education among female students, students with disabilities, and secondary students, as reflected in earlier portions of the literature review. Achievement among elementary students has not been studied as thoroughly, thus the focus of the current study.

In a study from Guzey et al. (2017), students in 4^{th}-8^{th} grade mathematics were pre- and post-tested in science and mathematics after the implementation of STEM units. These researchers used single-level regression analysis to determine if STEM integration had an impact on tests given in mathematics, science, engineering, and the state-mandated standardized test. While Guzey et al. found an increase in one set of science tests, the other analyses of the tests did not show a significant increase. Crotty et al. (2017) studied engineering assessment results from students in 4^{th} to 9^{th} grades after integration of STEM. These researchers found engineering assessment results were positively impacted by the integration of STEM with a focus on the engineering portion of STEM. These studies included elementary students, but did not focus on those in particular and provided mixed results concerning the impact of STEM education on academic assessments.

Judson (2014) compared mathematics, language, and science test scores of students enrolled in traditional programs to those of students enrolled in STEM-focused magnet and charter schools. Judson found slightly higher scores for those students enrolled in the STEM-focused charter schools versus those enrolled in a traditional program. The magnet schools did not show any significant difference in test scores. This study is important to the current research, but does not address public schools' implementation of a STEM-focused curriculum.

Acar et al. (2018) conducted a study examining the impact of STEM integration on the mathematics and science scores of 4^{th} grade students. In this study, researchers found both mathematics and science post-test scores were increased in their experimental groups. While both mathematics and science scores showed an increase, Acar et al. found science scores to be a greater increase. While this study is similar to the current study, it was conducted in Turkey. The results show promise for the current study, and this study will add to the literature concerning American schools implementing elementary STEM-focused education.

From a different perspective, Dickerson et al. (2014) looked at the effect of a pull-out STEM program on the academic achievement of students' standardized test scores in English, math, and science. No statistical difference was found in any standardized test scores between students who received pull-out STEM instruction and those who were not a part of those services. Dickerson et al. cited the idea that often when elementary school instruction is diverted from basic instruction in the core subjects to something like STEM, that scores may suffer. These researchers did not find this to be the case for this study.

As the focus on STEM becomes greater in the world, the impact of a STEM-focused curriculum in elementary school will become more important. Current research exists concerning academic achievement in elementary school, but more research is needed to add to the field. Educators must have research to back STEM implementation, and more research to understand its effectiveness. This study will add to that literature, and address the gap that currently exists within research surrounding STEM education and elementary school students.

Summary

STEM is not likely to leave the educational world anytime soon, and it is important for educators to continue to look at research concerning its impact on education. John Dewey's belief in progressive education and the scientific method fully support STEM education as being beneficial to students. Bandura's social cognitive theory demands students work with their environment, both in the physical and social sense. STEM education requires such collaborative learning and real-world problem-solving. STEM education falls directly in line with the belief that students need hands-on, inquiry-based curricula.

Understanding STEM and its impact on education is important. Defining STEM education has been, and will most likely continue to be, a difficult task. We must bring together the literature to support a broad definition of STEM education, and understand that integration and practice will not be the same at all levels. Terms like the STEM pipeline must be understood to gain an understanding of the STEM's importance to the educational scene, and ultimately to our future job market. Teacher preparation becomes an important part of this research, as this goes hand-in-hand with preparing students for the STEM-focused world.

Research currently exists concerning STEM education and its impact on middle, secondary, and post-secondary education, both in terms of academic achievement and interest in STEM fields. Underrepresented groups, students with disabilities, and females are groups who are denoted in the research on STEM education. When looking into STEM education and elementary school, of primary interest to the current study, elementary students and their interest in STEM is a field receiving more attention. Few studies, however, exist concerning how STEM education impacts elementary students' academic achievement scores. This is important because of the focus on the importance of fostering students ready for our STEM-focused job market and world. The research in the current study will add to the body of knowledge in this particular field, and add to literature concerned with the justification of STEM education.

CHAPTER THREE: METHODS

Overview

STEM and its integration in the American educational system continues to be a highly discussed topic in educational research (Holmlund et al., 2018). The current study investigated a causal relationship between STEM-focused programs and their impact on academic achievement at the elementary level. Chapter Three addresses the design of the study, research questions, participants and setting, instrumentation, procedures, and data analysis.

Design

For the purpose of this research, the researcher examined a possible cause-and-effect relationship between STEM-focused programs and their effect on fifth grade students' standardized test scores. Research that endeavors to explain, or to some degree find evidence to suggest a cause-and-effect relationship is best served by a causal-comparative research design (Gall et al., 2007).

The independent variable, students who experienced a STEM-focused education or those who did not, was not manipulated by the researcher. According to Gall et al. (2007), causal-comparative research designs are nonexperimental, and require an independent variable that can be measured categorically. The categories of the independent variable for this study were students who experienced STEM-focused curriculum and those who did not. Gall et al. also state that causal-comparative research best fits the definition for ex-post facto research, which means research that does not require the researcher to manipulate the independent variable. For this study, manipulation of the independent variable was not necessary and all research was conducted after the tests being studied, which made this ex-post facto research. Along these same lines, Creswell and Guetterman (2019) describe this as using a post-test only design, since for this study, the researcher only looked at the independent variable's effect on the dependent variable, without any pretesting.

The dependent variables for this study were the test results from standardized tests taken by fifth grade students in both mathematics and science. The researcher did not conduct any pretesting, again making this a post-test only design (Creswell & Guetterman, 2019), but only looked at test results that have already occurred.

Research Question

RQ: Is there a difference in fifth grade students' science and math achievement scores between students who experience STEM-focused curriculum and those who experienced a traditional math and science curriculum?

Hypothesis

The null hypothesis for this study is:

H_0: There is no significant difference in fifth-grade students' science and math achievement scores between students who experience STEM-focused curriculum and those who experienced a traditional math and science curriculum.

Participants and Setting

For this study, the participants were chosen from a population of fifth grade students within a Virginia school district. The school district is considered a rural school district, with between 40% and 50% of all students economically disadvantaged. The school district includes less than 4% of students as English Language Learners (ELL), 23% fall into a racial or ethnic group other than white, and 17% are considered students with disabilities. The period of time was from the SOL testing session that concluded the 2018-2019 school year.

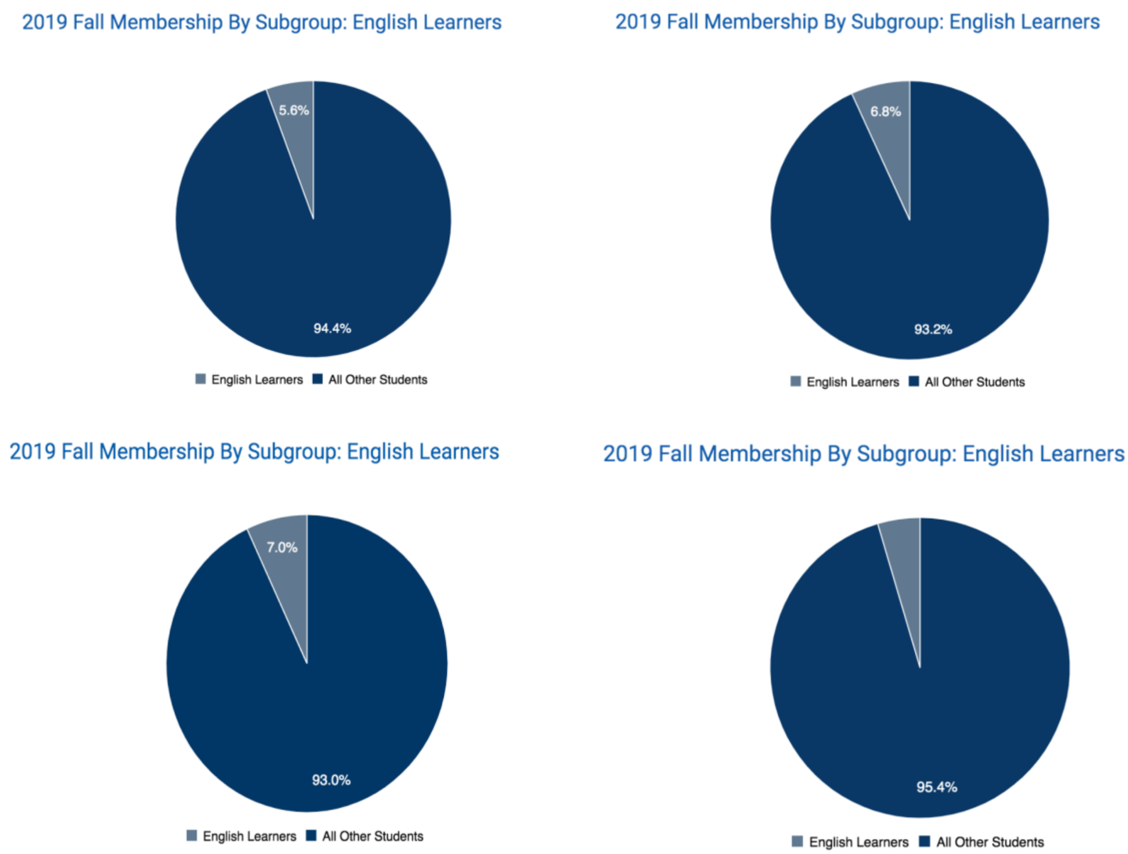
Convenience sampling was used to choose the population for this study, as the students were already grouped into fifth grade classes who either experienced a STEM-focused curriculum or fifth grade classes who did not have this experience. According to Gall et al. (2007), convenience sampling requires a selection of a sample that is convenient to the researcher and suits the purpose of the study. The researcher worked within the school district from which the sample was chosen. The researcher chose this school district because of her employment and due to knowledge of schools that had STEM-focused programs at the elementary level, and knowledge of schools within the district that did not have STEM-focused programs at that level.

For this study, a sample size of 48 for each of the four groups was chosen. This meets the requirements for a multivariate analysis of variance (MANOVA). This number meets the minimum requirement, which is a sample size of 48-62 for each group, when assuming a medium effect size with statistical power of 0.80 at the 0.05 alpha level (Warner, 2013). According to those sizes for the four groups, the minimum total for the study would be 192, with these groups satisfying the minimum requirements. The groups consist of those students who received a STEM-focused curriculum and those who did not, two classes of students taken from each.

The sample chosen included students from four elementary schools within the Virginia school district. These schools, School A, School B, School C, and School D, were matched according to ethnicity, socioeconomic status, and English Language Learners (ELL). Schools A and B were the schools chosen as having a STEM-focused curriculum and Schools C and D as receiving the traditional mathematics and science curriculum. The statistics for each of the schools are included in Figures 1, 2, and 3 below. According to these figures for the schools' populations for the 2019 school year, the matching procedure has been properly used so that extraneous variables do not confound the study (Gall et al., 2007).

Figure 1

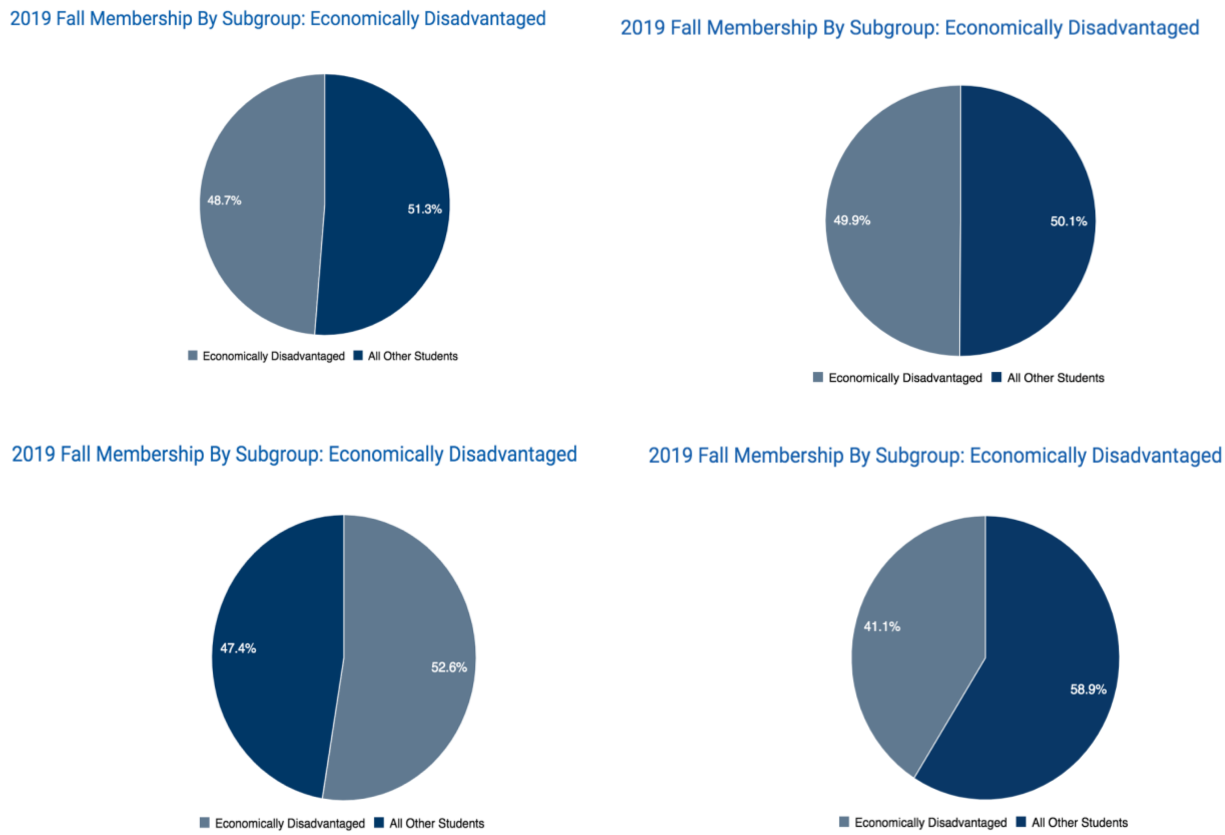
ELL Enrollment of Total School Population



Note. This figure demonstrates the enrollment of ELL students at Schools A and B (top) and Schools C and D (bottom) (Virginia Department of Education, 2019).

Figure 2

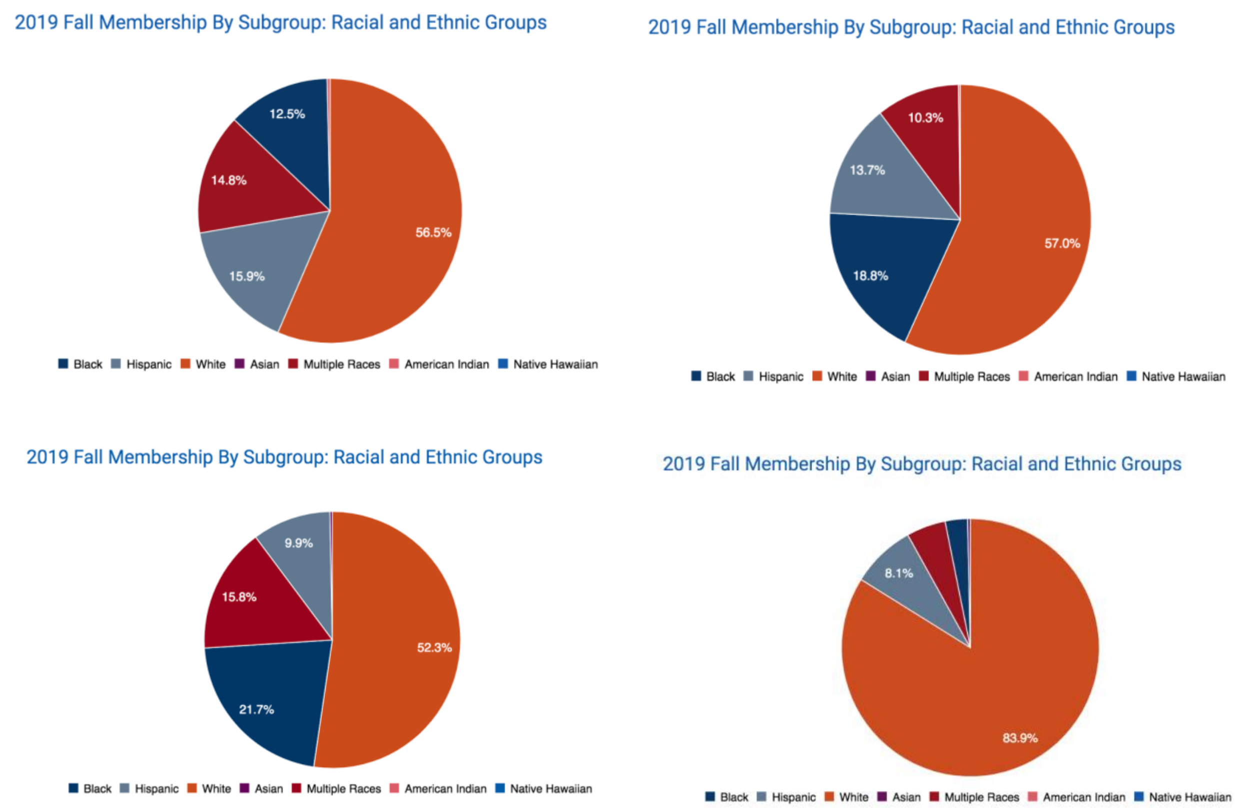
Economically Disadvantaged Enrollment of Total School Population



Note. This figure demonstrates the enrollment of economically disadvantaged students at Schools A and B (top) and Schools C and D (bottom) (Virginia Department of Education, 2019).

Figure 3

Racial and Ethnic Group Enrollment of Total School Population



Note. This figure demonstrates the racial and ethnic distribution of students at Schools A and B (top) and Schools C and D (bottom) (Virginia Department of Education, 2019).

For the four schools chosen, the STEM-focused schools and the traditional curriculum schools, matching procedures were used. For this study, Schools A and B had 52 girls and 68 boys, 41% of students who were considered belonging to a minority or ethnic group, and a percentage of 45% considered economically disadvantaged. Schools C and D had 42 girls and 64 boys, 24% of students belonging to an ethnic or minority group, and 40% considered economically disadvantaged. According to Gall et al. (2007), this matching technique equated the two groups for purposes of studying the causal relationship defined by the study. These were naturally occurring groups, as these students were already grouped into fifth-grade classes.

Instrumentation

The instrument used in this study to assess students' performance in mathematics and science in 2019 was the 2019 Virginia Standards of Learning (SOLs) Assessment in Mathematics and Science. The purpose of the Virginia Science and Mathematics SOL tests is to evaluate minimum academic proficiency in each subject area. The Virginia SOLs are a set of standards for each grade level and each subject taught in grades kindergarten through 12th grade. The SOLs came about in 1995, when a set of minimum standards was created in the subject areas of reading, mathematics, science, and social studies. Over the last 25 years, these standards have widened to include all subjects taught in Virginia schools. The first tests used to measure students' acquisition of knowledge based on these standards were created in 1996-1997 and administered in 1998. A team of teachers, curriculum specialists, and other educators created these assessments. In 2000, the Virginia Board of Education decided that the standards and assessments should be reviewed on a cyclical basis, and therefore, a review cycle of every seven years was implemented for each core area (Virginia Department of Education, 2014).

The No Child Left Behind (NCLB) Act of 2001 required each state to provide evidence of meeting basic standards for each student. Virginia's SOL tests were determined to meet these rigorous criteria for testing standards under NCLB, and these tests were used as assessment of whether schools and districts met Adequate Yearly Progress (AYP) under NCLB (Virginia Department of Education, 2014).

Virginia SOL tests have been used as instruments in other scholarly studies. Malone et al. (2019) looked at pass rates on SOL tests based on grade configurations in several different schools. Brunn-Bevel and Byrd (2015) also used these standardized tests to study underrepresented student groups and their pass rates. Wilkins et al. (2003) looked at the correlation between time students spent studying art, music, and physical education and SOL pass rates.

The SOL tests are administered in grades 3-12 at the end of courses. In the elementary and middle grades, the tests are grade dependent, and are given at the end of the year. Some of the high school SOL tests are subject dependent, such as history tests, social sciences, mathematics, and science, and are given at the completion of the course. The tests are composed of mostly multiple-choice questions, with some technology-enhanced items included in each assessment. The number of items included on the assessment can be found on the VDOE webpage in the testing blueprints for each test. For the fifth-grade Mathematics SOL test, this test was given to students in Virginia school districts as a computer adaptive test. This means the test responds to students' answers during the test, and gives future items based on their competency with responses. The 2019 Mathematics SOL test had 40 test items, with 35 operational items, five field test items which did not count in scoring, and were given online to all students in the Virginia school district (Virginia Department of Education, 2019). The 2019 Science SOL test was a 50-question online test, which was not computer adaptive. The test contained 40 operational items and 10 items considered field-test items, which did not count in students' scores (Virginia Department of Education, 2013).

Virginia SOL assessments are administered three times a year; fall, spring, and summer. They are almost totally administered online, with paper-pencil administration being given only to students with documents requiring such. Test administration is completed at the school level, with test administrators required to sign testing agreements, participate in testing training sessions, and use a manual provided by the VDOE. Students with Individualized Education Plans (IEPs) and 504 plans are given accommodations for testing according to their associated documents. When scored, raw scores, or the number of items a student answered correctly, are equated to scaled scores. The total scale score for each test is 600 points, which is equated to the raw scores the student receives. Each test requires a minimum score of 400 in order to be considered passing at the pass/proficient level, and requires a score of at least 500 for a pass/advanced score (Virginia Department of Education, 2014). Tests are untimed, but must be completed within the school day unless otherwise noted in the testing manuals.

For the development of test items, a panel of experts are assembled each time a subject area is up for review. The VDOE trains item-writers to initially write test questions. These individuals are trained on the content presented in the Virginia SOLs for the subject area and what the minimum knowledge sets are for the subject area. The validity of test questions are assured by content-area experts and a team of educators and editors who review the test questions for fairness, accessibility, and overall usability of the items (Virginia Department of Education, 2014).

According to Gall et al. (2007), Cronbach's Alpha is used to determine consistency of test items, or the probability that test takers will answer similar questions in a similar way. Reliability for the 2019 Virginia Mathematics Standards of Learning assessment was determined using Cronbach's Alpha for each core version of the test. Two versions, one and two, are given to each school division during test administration. For core version one, α=.92, and for core version two, α= .91 (Virginia Department of Education, 2014, p. 51). Reliability for the 2019 Virginia Science Standards of Learning assessment was also determined using Cronbach's alpha analysis. For the core version one, α= .86, and for core version two, α= .88 (Virginia Department of Education, 2014, p. 52). For each of these tests, both versions meet acceptable levels of Cronbach's alpha, ensuring their reliability.

Validity is measured by how appropriate, meaningful, and useful conclusions made from test scores are concerning any given assessment (Gall et al., 2007). Content validity is considered, “the degree to which elements of an assessment instrument are relevant to and representative of the targeted construct for a particular assessment purpose” (Haynes et al., 1995, p. 239). The curriculum framework is used as a guide when creating test items and test versions. This curriculum framework provides knowledge and skills necessary for each strand of the particular subject area being tested. The test blueprint, published before SOL tests are administered, provide a breakdown of how many test questions and what kind are to be seen on the test from each strand of the curriculum framework. Test forms are reviewed several times by both VDOE auditors, as well as Virginia educators, to ensure that test items are properly related to the content standards. The VDOE also used Virginia Commonwealth University’s education department to review test items and test forms in order to ensure validity (Virginia Department of Education, 2014).

Procedures

In order to begin this research study, the researcher identified, through matching techniques, the schools to be studied. First, a definition of a STEM-focused school and a traditional school was researched and defined. For the purposes of this study, a STEM-focused school is one whose curriculum is STEM-focused, uses technology, applies STEM to real world situations, and employed a STEM teacher or specialist (Holmlund et al., 2018, & Slavit et al., 2016). A traditional mathematics and science school does not have these offerings as part of their curriculum. Once these were defined, the researcher made a listing of all elementary schools within the Virginia school district. Of these, each school was categorized as either STEM-focused or traditional. From this listing, the researcher chose schools with comparable demographics and enrollment numbers as defined by the Virginia Department of Education (2019).

In order to conduct research, the researcher first submitted a request to the Virginia school district, in the form of a letter through email, for approval to conduct the study using four of the district's elementary school data (see Appendix A). Approval was granted in the form of an emailed letter in March of 2021 (see Appendix B). Once this approval had been granted, the researcher then applied to Liberty University's Internal Review Board (IRB) requesting permission to conduct research. This permission was granted in March of 2021 (see Appendix C).

Once approval was obtained from the IRB and the school district, the researcher requested needed data from the district's testing coordinator. The testing coordinator provided the data in a Microsoft Excel spreadsheet, with all names and identifiers removed. The researcher requested score reports for the four elementary schools that included pass rates in mathematics and science for the 2019 administration of tests in fifth grade, along with demographic data for each student. According to Gall et al. (2007), matching is a procedure "used to equate two groups on one or more extraneous variables so that these extraneous variables do not confound the study of causal relationships involving the variables of primary interest to the researcher" (p. 313). The researcher then matched students for the study according to gender, socioeconomic status, ethnicity, race, and special education status. Once this data had been matched, information was entered into the Statistical Package for Social Sciences (SPSS) for data analysis. This information was stored in a password-protected computer. Once data was stored, the researcher used SPSS to run statistical analysis of the matched data.

Data Analysis

For data analysis, SPSS version 24 was used. SPSS is the most commonly used software in educational research to analyze, manage, and display data (Gall et al., 2007). For the present study, a multivariate analysis of variance (MANOVA) was chosen. This was chosen to assess the two groups of students (independent variable) on more than one dependent variable, the students' standardized test scores in both mathematics and science. The MANOVA requires that each participant in the study have a score on at least two dependent variables (Gall et al., 2007). This analysis is favorable over an analysis of variance (ANOVA) due to the study having more than one dependent variable. "MANOVA evaluates whether the population means on a set of dependent variables vary across levels of a factor or factors" (Green & Salkind, 2017).

A MANOVA was used to evaluate the null hypotheses regarding the difference in mathematics and science standardized test scores between students who experienced a STEM-focused curriculum and those who did not. Box and whisker plots were used to detect any extreme outliers in the data set (Green & Salkind, 2017). In order to determine if the assumption of normality was met, the Kolmogorov-Smirnov test was used, since the sample size was greater than 50 (Warner, 2013). An alpha level greater than 0.05 indicated the assumption of normality had been met.

In order to assess the assumption of multivariate normal distribution, scatterplot matrices were created for each group of the independent variable, students receiving STEM-focused education and those receiving only a traditional math and science education. The researcher looked for the classic "cigar-shape" in the matrices to satisfy this assumption (Warner, 2013).

Using Box's M statistic, the assumption of homogeneity of the variance and covariances among the dependent variables was tested. To meet the requirements of homogeneity, $p > .05$.

If the *p* statistic failed this test, the researcher would have used Levene's test of homogeneity of variances to detect the problem in the data. The absence of multicollinearity was tested using a linear regression model. Correlation coefficients should have a value of 0.80 or lower in order to meet the assumption that the dependent variables are not too highly related resulting in multicollinearity. Once those assumptions were met, the MANOVA test was conducted (Green & Salkind, 2017).

When assumptions for the MANOVA had been met, the statistical analysis was run on the data. This included testing for the groups differing on the dependent variable using a general linear model. The *p*-value for Wilk's Lambda or Pillai's Trace should be less than .05 for any of the effects chosen, in order to reject the null hypothesis that there is no significant difference in students' scores (Gall et al., 2007). If there are violations to the assumption of homogeneity of variance and covariances, then Pillai's Trace should be used, as it is robust to these violations (Warner, 2013). Since these violations were not a concern, then Wilk's Lambda was used. Partial Eta Squared was used to measure effect size. Based on results indicated by the MANOVA, post hoc testing was required. This included one-way ANOVAs, with Tukey post-hoc tests to determine where significant differences existed (Green & Salkind, 2017).

CHAPTER FOUR: FINDINGS

Overview

This quantitative, causal comparative study was conducted to address whether a STEM-focused curriculum impacted standardized math and science test scores of students in fifth grade when compared to students who experienced a traditional math and science curriculum. The researcher looked at standardized test scores in math and science for the 2019 testing year of four elementary schools' fifth grade students. Two of the elementary schools implemented a STEM-focused curriculum, and two implemented a traditional math and science curriculum. For the purpose of establishing whether there was a significant difference between the test scores of the two curriculum types, the multivariate analysis of variance (MANOVA) was run on the data. Upon finding statistical difference, post hoc testing was conducted.

Research Question

RQ: Is there a difference in fifth grade students' science and math achievement scores between students who experience STEM-focused curriculum and those who experienced a traditional math and science curriculum?

Null Hypothesis

H_0: There is no significant difference in fifth-grade students' science and math achievement scores between students who experience STEM-focused curriculum and those who experienced a traditional math and science curriculum.

Descriptive Statistics

Descriptive statistics for this study were derived from data collected from a school district in the form of Virginia's Standards of Learning (SOL) assessments in mathematics and science. The possible scores on these tests range from a raw score of 0 to 600. Four schools, A, B, C, and D, made up the schools from which data were collected. Schools A and B were considered STEM-focused schools, while schools C and D were considered to have a traditional math and science curriculum or focus. From the grouping of traditional curriculum schools, 106 students' scores were included, for both math and science. For the STEM-focused schools, 120 students' math and science scores were included.

Data was originally gathered in a Microsoft Excel document, then entered in SPSS software (version 26) for data analysis. The descriptive statistics were analyzed using SPSS, for both the traditional and STEM-focused groups, and the sample size, means, and standard deviations are shown in Tables 1 and 2.

Table 1

Math SOL Scores

Descriptive Statistics

	N	Mean	Std. Deviation	Std. Error
STEM-focused	120	422.65	50.66	4.60
Traditional	106	446.37	50.00	4.89

Table 2

Science SOL Scores

Descriptive Statistics

	N	Mean	Std. Deviation	Std. Error
STEM-focused	120	414.32	64.00	5.64
Traditional	106	447.06	59.04	6.00

Results

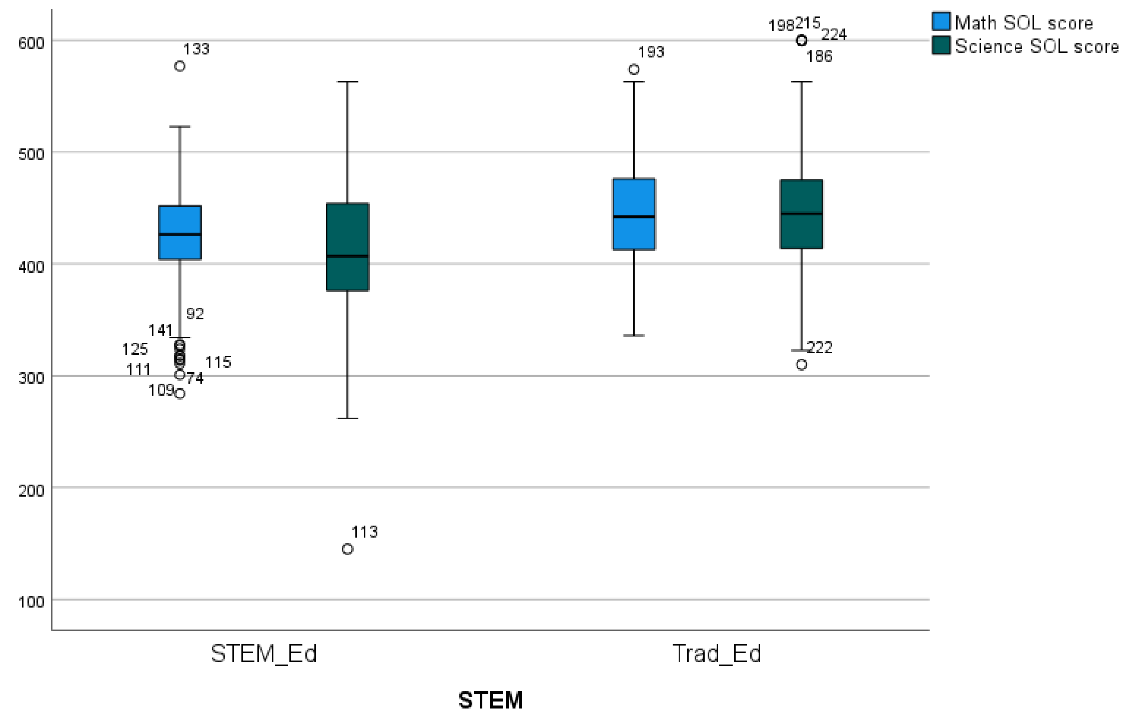
Assumptions Tests

Assumptions testing was conducted in order to satisfy the requirements of the statistical test, MANOVA. The first three assumptions of the MANOVA are covered through the causal-comparative design of the study (Warner, 2013). The two dependent variables, both measured at the continuous level, are science and math SOL scores. The second assumption requires one categorical variable with at least two independent groups, which in this case are schools with a STEM-focused math and science curriculum, and those with a traditional focus for these subjects. MANOVA requires independence of observations, which is satisfied through having separate groups of the independent variable, with no overlapping of participants across the groups.

The fourth assumption test for the MANOVA requires the data be screened for univariate and multivariate outliers. Boxplots were used to assess the presence of any univariate outliers, as noted in Figure 4.

Figure 4

Boxplot for Inspection of Outliers



Note. Boxplot used for inspection of outliers in math and science SOL scores among the four schools, A, B, C, and D.

Upon examination of the boxplot, outliers were discovered. Data were checked to ensure entry was correct, and all entries were found to be correct. There were no measurement errors detected either, therefore, these outliers can be considered genuinely unusual data points. With the data being normally distributed, the researcher decided to include these outliers in the data set, in order to remain transparent and honest in the reporting of results, and continue with analysis (Warner, 2013).

When testing for the assumption of multivariate outliers, Mahalanobis distance was used, as this is the recommendation for detecting multivariate outliers when using MANOVA for statistical analysis (Warner, 2013). With having two dependent variables, the value for

Mahalanobis distance was compared against the chi-square distribution, with degrees of freedom being the number of dependent variables, two. With these parameters, and an alpha level of .001, the cut-off value for Mahalanobis distance was 13.82. One multivariate outlier was noted, having MAH=19.737. Data for this case was reviewed for accuracy, and it was determined that neither data entry error nor measurement error occurred. Again, this was considered a genuinely unusual data point, however, the researcher decided to include the point for accuracy of data reporting and analysis.

MANOVA requires data need to have multivariate normality, which was assessed through the Kolmogorov-Smirnov test. As demonstrated in Table 3, using the Kolmogorov-Smirnov statistics, normality was violated for both math and science SOL scores with STEM educated groups (p = .000, p = .001, respectively), and for science SOL scores with the traditional curriculum grouping (p = .010). Normality was tenable for math SOL scores in the traditional curriculum group (p = .200). As Tabachnick and Fidell (2013) point out, MANOVA is fairly robust to violations of normality, therefore, the researcher continued statistical analysis. Results from normality testing are included in Table 3.

Table 3

Tests of Normality

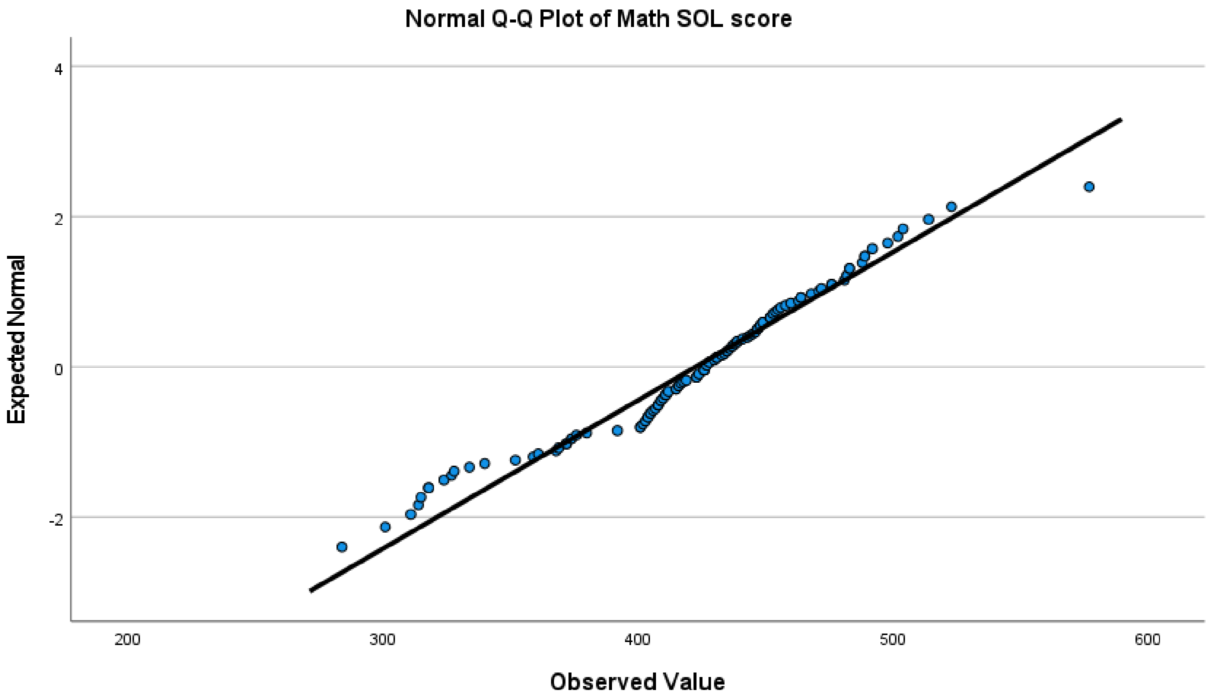
Test of Normality

		Kolmogorov- Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Math SOL Score	STEM Ed.	.135	120	.000	.967	120	.005
	Trad. Ed.	.045	106	.200*	.993	106	.856
Science SOL Score	STEM Ed.	.112	120	.001	.967	120	.005
	Trad. Ed.	.101	106	.010	.969	106	.015

In order to further ensure normality of the data, Normal Q-Q plots were created and visually inspected. The results of these plots are shown in Figures 5 and 6.

Figure 5

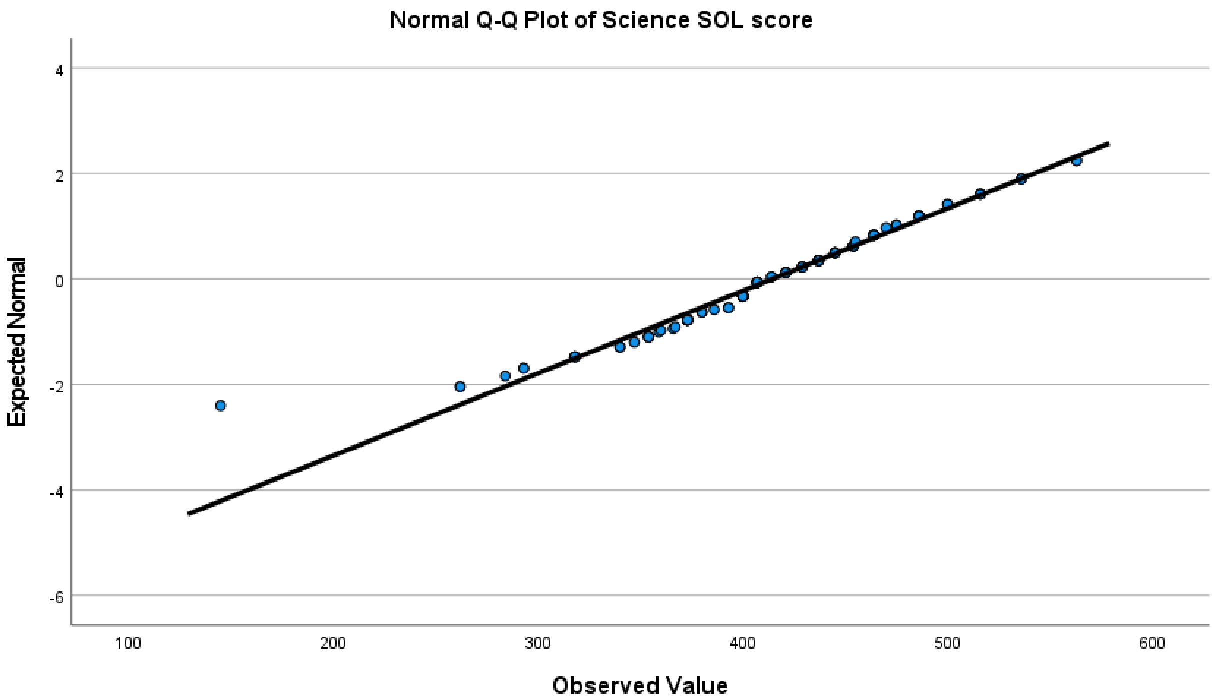
Multivariate Normality Math Scores



Note. Plot used to assess multivariate normality of math SOL scores.

Figure 6

Multivariate Normality Science Scores



Note. Plot used to assess multivariate normality of science SOL scores.

When examining the Q-Q Plots for both math and science SOL scores, the assumption of multivariate normality was met, and therefore, there was no need for transformation of the data.

When testing for multicollinearity, the researcher used Pearson's correlation coefficient to determine if the dependent variables were too highly correlated. The data were found to be highly correlated, but did not violate the assumption of no multicollinearity, as assessed by the Pearson correlation (r = .749, p = > .001) (See Table 4).

Table 4

Pearson Correlation Table

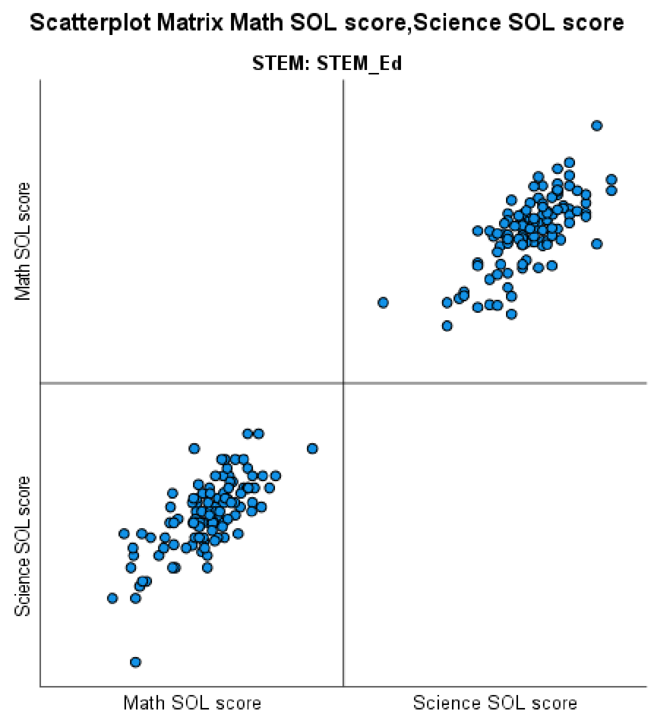
Correlations Table

		Math SOL score	Science SOL score
Math SOL score	Pearson correlation	1	.749
	Sig. (2-tailed)		.000
	N	226	226
Science SOL score	Pearson correlation	.749	1
	Sig. (2-tailed)	.000	
	N	226	226

The next assumption test for MANOVA requires data to be screened for a linear relationship between the dependent variables for each group of the independent variable. To ensure this, two scatterplot matrices were created for each school type, STEM-focused and traditional, then examined to determine whether a linear relationship was present (Warner, 2013). The scatterplot matrices are shown in Figures 7 and 8 below, and the linear relationship is present for both dependent variables.

Figure 7

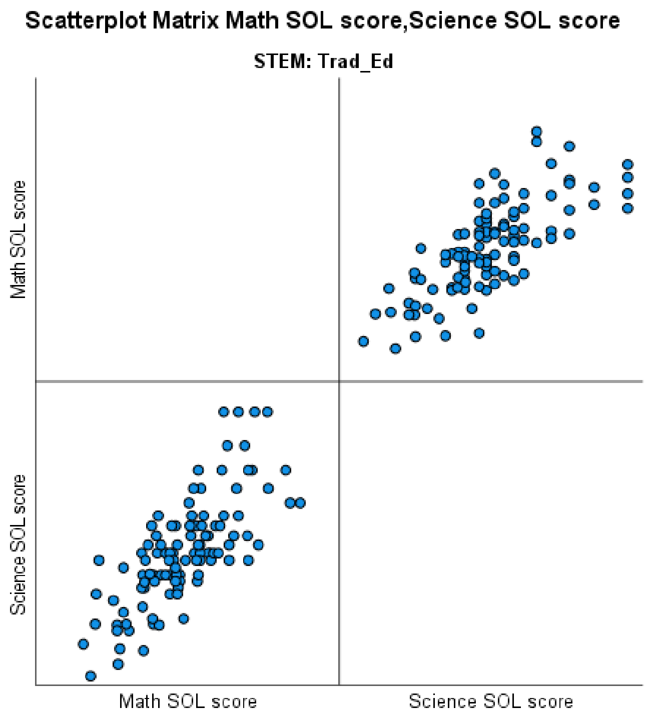
STEM Scatterplot Matrix



Note. Scatterplot matrix used to examine the linear relationship between math and science scores for STEM-focused schools.

Figure 8

Traditional Curriculum Scatterplot Matrix



Note. Scatterplot matrix for traditional curriculum schools used to examine the linear relationship between math and science SOL scores.

In order to meet the assumption of the homogeneity of covariances, Box's test of equality of covariances was used. When using this test, the researcher looked for a *p*-value greater than .001, which was found at $p = .660$. This indicated homogeneity of covariances had not been violated.

MANOVA Results

The assumptions of homogeneity of variance and covariances were not violated, therefore, the researcher decided to use Wilks' Lambda to report any statistical significance from the multivariate test. Results from the multivariate test are shown in Table 5.

Table 5

Multivariate Test

Multivariate Tests							
Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.987	8447.168	2.000	223.000	.000	.987
	Wilk's Lambda	.013	8447.168	2.000	223.000	.000	.987
	Hotelling's Trace	75.759	8447.168	2.000	223.000	.000	.987
	Roy's Largest Root	75.759	8447.168	2.000	223.000	.000	.987
STEM	Pillai's Trace	.069	8.289	2.000	223.000	.000	.069
	Wilk's Lambda	.931	8.289	2.000	223.000	.000	.069
	Hotelling's Trace	.074	8.289	2.000	223.000	.000	.069
	Roy's Largest Root	.074	8.289	2.000	223.000	.000	.069

Analysis of the multivariate test show a statistically significant difference between the schools, based on the combined dependent variables, $F(2, 223) = 8.289$, $p < .0001$; Wilks' $\Lambda = .931$; partial $\eta^2 = .069$. Since the *p*-value was less than .05 (Warner, 2013), the researcher rejected the null hypothesis stating there was no significant difference between the scores of the two school types. The researcher chose to continue with post hoc testing in the form of univariate one-way ANOVAs.

Post Hoc Testing

In order to further examine where statistically significant differences existed, the researcher conducted between-subjects effects tests, or multiple one-way ANOVAs. Results for this test are shown in Table 6.

Table 6

Univariate One-Way ANOVAs

Tests of between-subjects effects							
Source	Dependent variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Math SOL score	31661.540	1	31661.540	12.490	.000	.053
	Science SOL score	60330.143	1	60330.143	15.835	.000	.066
Intercept	Math SOL score	42504620.30	1	42504620.30	16767.642	.000	.987
	Science SOL score	41760092.69	1	41760092.69	10960.919	.000	.980
STEM	Math SOL score	31661.540	1	31661.540	12.490	.000	.053
	Science SOL score	60330.143	1	60330.143	15.835	.000	.066
Error	Math SOL score	567821.951	224	2534.919			
	Science SOL score	853419.627	224	3809.909			
Total	Math SOL score	43123683.00	226				
	Science SOL score	42637534.00	226				
Corrected Total	Math SOL score	599483.491	225				
	Science SOL score	913749.770	225				

Based on results from the ANOVAs, a statistically significant difference was found between math scores of students attending STEM-focused and traditional curriculum schools, $F(1, 224) = 12.490$. $p < .001$; partial $\eta^2 = .053$. Students in the traditional school scored higher on the math assessment ($M = 446.37$ $SD = 50.00$) than students in the STEM school assessment ($M = 422.65$ $SD = 50.66$).

A statistically significant difference was also found between science scores of students attending STEM-focused and traditional curriculum schools, $F(1, 224) = 15.835$. $p < .001$; partial $\eta^2 = .066$. Students in the traditional school scored higher on the science assessment (*M* = 414.32 *SD* = 59.04) than students in the STEM school assessment (*M* = 447.06 *SD* = 64.00).

Since there are two dependent variables, a Bonferroni correction was made, meaning in order to assert statistical significance, $p < .025$, instead of $p < .05$. Even with this correction, both math and science scores for the two groups show statistically significant differences, $p < .0005$. The researcher rejected the null hypothesis stating no significant difference when comparing math and science SOL scores of STEM-focused and traditional curriculum schools.

Tukey post hoc tests were conducted to determine where significant differences existed within the data. For math standardized tests, schools C and D (traditional curriculum) had higher mean scores than schools A and B (STEM-focused curriculum). For math scores, school A had a statistically lower mean than schools C and D, at $p = .025$ and $p = .004$, respectively. School B's mean scores were lower than both C and D, but only significantly lower than School D ($p = .25$).

For science scores, there was a similar finding. The means of science scores for schools C and D were higher than school A at a significant level ($p = .001$ for both). School B was lower than schools C and D as well, although not at a level of significance ($p = .336$, $p = .462$, respectively). Overall, schools C and D were higher in their means for both math and science standardized test scores than schools A and B. School A's mean score was statistically lower with significance when compared to schools C and D for both math and science. School B showed significance only when compared to school D for math. Table 7 displays results from the Tukey post hoc testing.

Table 7

Tukey HSD Multiple Comparisons

Multiple Comparisons					
			Mean Difference	Std. Error	Sig.
Math SOL Score	School A	School B	-13.48	9.187	.862
		School C	-28.37*	9.779	.025
		School D	-32.39*	9.303	.004
	School B	School A	13.48	9.187	.862
		School C	-14.89	9.707	.759
		School D	-18.91*	9.227	.250
Science SOL Score	School A	School B	-23.36*	11.211	.230
		School C	-46.12*	11.934	.001
		School D	-43.37*	11.353	.001
	School B	School A	23.36*	11.211	.230
		School C	-22.76	11.846	.336
		School D	-20.01	11.260	.462

*The mean difference is significant at the .25 level.

CHAPTER FIVE: CONCLUSIONS

Overview

The current 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. The following chapter addresses a discussion of results from the current study, implications from those results, limitations of the study, and recommendations for future research.

Discussion

The purpose of this quantitative, causal-comparative study is to examine the impact on the academic achievement of students in schools with STEM-focused programs or curriculum. The research hypothesis stated there was no statistically significant difference between the standardized test scores of students who experienced a STEM-focused curriculum and those who experienced a traditional math and science curriculum. Standardized test scores in math and science were used from four elementary schools, two schools with a STEM-focus and two schools with a traditional math and science focus. Scores from fifth grade end-of-year tests in math and science were taken from schools A and B (N=120), those students having experienced a STEM-focused curriculum. Scores were also taken from schools C and D (N = 106), those students having experienced a traditional math and science curriculum.

Results from the MANOVA showed a statistically significant difference between the math and science standardized test scores according to the grouping of the independent variable (STEM-focused and traditional curriculum). Post-hoc testing was conducted to determine where statistical differences existed, and it was found both math and science scores between the two types of schools to have statistically significant differences. There was a statistically significant difference in math exam scores between the fifth grade students attending schools with different curriculum focuses, $F(1, 224) = 12.490$, $p < .001$; partial $\eta 2 = .053$. There was also a statistically significant difference in science exam scores between the fifth grade students attending schools with different curriculum focuses, $F(1, 224) = 15.835$, $p < .001$; partial $\eta 2 = .066$. A Bonferroni adjusted α level of .025 was used for both, as there were two dependent variables. Post hoc testing showed STEM schools, across math and science standardized test scores, were lower than schools with a traditional curriculum.

According to current research on STEM implementation in elementary school, there are studies to support the findings of this study. Guzey et al. (2017) found STEM implementation to have little impact on standardized test scores of students in fourth to eighth grades. This is similar to the findings of the current study, 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. These researchers did not look at a full STEM-focused program, but at 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. Both of these studies support findings from the current study, however, like the current study, each of these cases had a very different implementation of STEM education. Guzey et al. looked at individual units of science education with a STEM focus, while Dickerson et al. addressed the effects of a pull-out STEM program. These are both significantly different from the STEM implementation included in the current study.

Likewise, Patel et al. (2019) looked at four high schools with varying levels of STEM implementation. These researchers similarly found no significant impact on test scores despite the level of STEM implementation. Saw (2019) and Bicer and Capraro (2019) each looked at Texas STEM academies and their impact on academic achievement. Each found the STEM implementation at the secondary level to have no statistically significant impact on standardized test scores in math, nor on academic achievement in terms of grades or GPA. While these studies support the findings of the current study, they are from data at the secondary level, which is much different than data at the elementary level.

In contradiction to the results of this study, Acar et al. (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. Similar to the current study, but drawn from middle school data, 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. Guzey et al. (2016) also found STEM implementation at the middle school level to have a positive impact on science test scores. Additionally, Morrison et al. (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. While these studies seem to contradict the results of the current study, they are not drawn from elementary data.

While this study did not address students' attitudes towards STEM education, it is important to note the number of studies in support of this. From elementary data, Sullivan and Bers (2019), Parker et al. (2015), Graves et al. (2016), and Babarovic et al. (2018) found students' interests and attitudes to be positively impacted with the implementation of STEM interventions and education. Koul et al. (2018) also found STEM implementation to have a positive impact on middle school students' interests and attitudes toward STEM and STEM careers. While this neither supports nor contradicts the current study, it is important to note the positive impact of STEM education beyond academic achievement.

Implications

Data from this study implied STEM-focused education did not have a positive impact on standardized test scores in math and science, but rather, the opposite. Data from this study indicated the traditional curriculum supported more achievement in terms of standardized test scores. This is an interesting finding, as STEM is so strongly pursued by educators and employers alike (English, 2016; Leung, 2020; & Mendick et al., 2017). However, the researcher does not believe this negates the importance of STEM education, and the importance of this study.

It is important for educators, policy makers, and the global community to understand the ways in which educational trends impact student learning. STEM is relatively new to the educational scene, in terms of the history of education. Without research to understand the ways in which STEM impacts education, educators and students will not be able to fully realize the benefits. The current study does not support elementary achievement on standardized tests with the implementation of STEM education, and this is something that is important to educators from elementary school and beyond. Educators and policy makers should begin to ask questions about where STEM education should begin, what it should look like, and how far its impact extends.

Such a great understanding of STEM education and its impact exists at the middle and secondary level, as was evidenced in Chapter Two. The current study adds to the body of knowledge concerning STEM education at the elementary level, but it is a small part of what needs to be researched. Results from the current study support a lack of academic gain, in terms of standardized tests, from STEM education, and this should concern educators and researchers alike. This research brings about many more questions along with its results, including questions of why was this the case for this particular study. With more funding being directed in support of STEM education, it is crucial to have more understanding of what this means for standardized testing, as this testing seems unlikely to leave education anytime soon. It is important to continue looking into elementary STEM education, as this study only scratched the surface of the benefits, or drawbacks, of STEM education at the elementary level.

As STEM continues to make its way into the educational spotlight, especially at the elementary level, the researcher believes this study will become an important comparative study for the future. Very little knowledge of STEM implementation at the elementary level exists at this point, therefore, this research becomes extremely important to current educational research and to future research as well. In order for educators to make an informed decision about what style of curriculum to choose and implement, a wealth of research must be available on its benefits, drawbacks, and best practices. If, in fact, STEM education does not support academic gain, then educators must decide on where its value lies, if it does have value in education. If STEM education can provide academic gain to students at the elementary level, then researchers and educators must begin to explore ways to ensure this gain occurs.

Limitations

Lesseig et al. (2019) addressed in great detail the lack of a clear definition of STEM education. Many researchers have cited the lack of definition to STEM education at all levels of school (English, 2016; Kelley & Knowles, 2016; & Xie et al., 2015). This lack of a clear and concise definition of STEM integration could be considered a limitation of any study concerning

STEM education. As discussed in Chapter Two, STEM integration can be anything from an after-school activity to a full implementation of a curriculum (Barrett et al., 2014; & Saw, 2019). Without a clear definition for educators to draw from, it becomes extremely difficult, if not impossible, to implement a program with fidelity. These STEM-focused schools from the current study utilized a STEM coach, STEM lab, and a STEM-focus within their mission statement or school improvement plan. While this fits the definition for the current study of a STEM-focused school, this is certainly not a universal definition. Subsequently, there were no state or national standards in place that would keep educators in the current study's school district adhering to any particular style of instruction, be that traditional or STEM-focused.

Another limitation of the current study is the variability of teacher training. While STEM implementation may have occurred as it was outlined in the school's improvement plan or mission statement, there were no guidelines outlined on teacher training for the implementation of this STEM education. This has been cited in literature as a criticism of STEM education (Nesmith & Cooper, 2019; & Sanders, 2009), and this lack of training would allow for a varied implementation by each teacher. Without training, which may or may not occur within districts at various levels, the implementation of STEM education cannot be consistent. A lack of consistency could certainly be the case within this district. Wu et al. (2019) suggest teacher training is of much importance to STEM implementation, and this would perhaps bridge the gap between what is expected of STEM-focused schools.

Inquiry-based teaching, which is in line with STEM education (DeCoito & Myszkal, 2018), may not lend itself well to scores on standardized tests. Tretter and Jones (2003) looked at inquiry-based teaching styles and their impact on standardized test scores. These researchers found the inquiry-based teaching style, which is akin to STEM-focused instruction, to be misaligned with instruction designed to improve standardized test scores. The benefits of an inquiry-based instruction or STEM-focused education reach far beyond standardized test scores, however, at least for the current study, this could be considered a limitation. The true academic benefits of a STEM-focused education may not be able to be fully realized from one set of standardized test scores.

Within the district from which data was drawn, the enactment of STEM-focused programs at the two schools had only occurred at full implementation for two full years at both STEM-focused schools. Content for the math and science SOL tests was taught through this STEM-focused curriculum, as the fifth-grade math content is taught during the fifth-grade year, and science content for the science SOL is taught in fourth and fifth grades. However, this may not have been enough time for the program to reach its full potential of instructional value.

Causal comparative research brings with it limitations as well. Causal comparative research is nonexperimental in nature; therefore, the researcher cannot truly make a claim of causality. The researcher used convenience sampling for participants in this study, which would allow for variables that could impact the results of the study beyond the control of the researcher. Without having control over the participants in the group, it would also be difficult to generalize results beyond the current study's population, let alone to the entire population (Salkind, 2010). With causal comparative research, especially with looking at a single study, it is impossible to determine if the chosen independent variable was the cause of change in the dependent variable. Without testing multiple theories of change in the dependent variable, it is impossible to say the chosen independent variable was the cause of any significant difference found (Salkind, 2010).

Last, this study was conducted using data from four schools within one school district. This school district can be considered rural, and is a small school district compared to many within the same state. The current study cannot be seen as representative of any urban school district data, nor representative of any findings from larger district with more possible resources.

Recommendations for Future Research

Future research is necessary to increase the body of knowledge that exists concerning STEM implementation and its benefits at the elementary level. The following are recommendations for future research:

1. A similar study should be conducted with a larger sample population in an urban school district in order to address differences that may exist between school district's implementation of STEM education.
2. A mixed-methods or qualitative study should be conducted to address the potential benefits of a STEM-focused school on fifth grade students' attitudes towards math and science.
3. An additional quantitative research study should be conducted, using a similar population, with consideration given to a longer-running program of a STEM-focused curriculum.
4. Research should be conducted on a larger scale, with similar populations, in order to add more valuable data to the subject of STEM integration at the elementary level.
5. Research should be conducted addressing a STEM-focused education and its impact on other forms of standardized testing, or other tests in general.
6. A case study of a particular school, or few schools, with a STEM-focused curriculum should be conducted in order to assess where teachers, administrators, and students feel benefits and drawbacks of this type of curriculum exist.

7. The current study should be repeated, using a mixed-methods approach, to assess not only students' academic achievement in terms of standardized tests, but also the growth they feel they have had through the experience with a STEM-focused curriculum.

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APPENDIX A

Letter of Permission Request

March 18, 2021

Dr. Bernice Cobbs
Franklin County Public Schools
Superintendent of Schools
[redacted]

Dear Dr. Cobbs:

As a graduate student in the School of Education at Liberty University, I am conducting research as part of the requirements for an Educational Doctorate. The title of my research project is The Impact of STEM Education on Elementary School Math and Science Achievement and the purpose of my research is to discover any relationship between an integration of STEM education and its impact on Virginia SOL test scores in math and science at the end of the fifth-grade year.

I am writing to request your permission to access and utilize archival standardized test scores from the 2018-2019 Grade 5 Virginia Standards of Learning Assessments in math and science.

The data will be used to analyze a possible cause and effect relationship between STEM education and standardized test results in math and science at the end of the fifth-grade year.

Thank you for considering my request. If you choose to grant permission, please provide a signed statement on official letterhead indicating your approval or respond by email to [redacted] A permission letter document is attached for your convenience.

Sincerely,

Jessica Bentley

APPENDIX B

Letter of Permission from School District

FRANKLIN COUNTY PUBLIC SCHOOLS
Office of Superintendent
25 Bernard Road • Rocky Mount, VA 24151-6614
(540) 483-5138 • FAX (540) 483-5806

March 23, 2021

Ms. Jessica Bentley
[redacted]

Dear Ms. Bentley:

After careful review of your research proposal entitled The Impact of STEM Education on Elementary School Math and Science Achievement, I have decided to grant you permission to receive and utilize the SOL test scores in Mathematics and Science from the 2018-2019 school year for your research study.

Please note the following:

☑ The requested data WILL BE STRIPPED of all identifying information before it is provided to the researcher.

☑ We are not requesting a copy of the results upon study completion and/or publication.

I wish you the best as you complete your research project.

Sincerely,
[redacted]

Dr. Bernice Cobbs
Division Superintendent

cc: Ms. Sue Rogers, Assistant Superintendent
Ms. Kara Bernard, Division Testing Coordinator

APPENDIX C

IRB Letter

LIBERTY UNIVERSITY.
INSTITUTIONAL REVIEW BOARD

March 29, 2021

Jessica Bentley
Kevin Struble

Re: IRB Exemption - IRB-FY20-21-730 The Impact of STEM Education on Elementary School Math and Science Achievement

Dear Jessica Bentley, Kevin Struble:

The Liberty University Institutional Review Board (IRB) has reviewed your application in accordance with the Office for Human Research Protections (OHRP) and Food and Drug Administration (FDA) regulations and finds your study to be exempt from further IRB review. This means you may begin your research with the data safeguarding methods mentioned in your approved application, and no further IRB oversight is required.

Your study falls under the following exemption category, which identifies specific situations in which human participants research is exempt from the policy set forth in 45 CFR 46:
101(b):

Category 4. Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met:

(i) The identifiable private information or identifiable biospecimens are publicly available;

(ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not contact the subjects, and the investigator will not re-identify subjects;

(iii) The research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under 45 CFR parts 160 and 164, subparts A and E, for the purposes of "health care operations" or "research" as those terms are defined at 45 CFR 164.501 or for "public health activities and purposes" as described under 45 CFR 164.512(b); or

(iv) The research is conducted by, or on behalf of, a Federal department or agency using government-generated or government-collected information obtained for nonresearch activities, if the research generates identifiable private information that is or will be maintained on information technology that is subject to and in compliance with section 208(b) of the E-Government Act of 2002, 44 U.S.C. 3501 note, if all of the identifiable private information collected, used, or generated as part of the activity will be maintained in systems of records subject to the Privacy Act of 1974, 5 U.S.C. 552a, and, if applicable, the information used in the research was collected subject to the Paperwork Reduction Act of 1995, 44 U.S.C. 3501 et seq.

Your stamped consent form(s) and final versions of your study documents can be found under the Attachments tab within the Submission Details section of your study on Cayuse IRB. Your stamped consent form(s) should be copied and used to gain the consent of your research participants. If you plan to provide your consent information electronically, the contents of the attached consent document(s) should be made available without alteration.

Please note that this exemption only applies to your current research application, and any modifications to your protocol must be reported to the Liberty University IRB for verification of continued exemption status. You may report these changes by completing a modification submission through your Cayuse IRB account.

If you have any questions about this exemption or need assistance in determining whether possible modifications to your protocol would change your exemption status, please email us at irb@liberty.edu.

Sincerely,
G. Michele Baker, MA, CIP
Administrative Chair of Institutional Research
Research Ethics Office