The Effects of STEM Integration on the Mathematics Achievement of Males and Females in Grades Three Through Eight

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The Effects of STEM Integration on the Mathematics Achievement of Males and Females in Grades Three Through Eight

A Field Study Report

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The College of Graduate Studies

Austin Peay State University

In Partial Fulfillment

Of

The Requirements for the Degree

Educational Specialist

Amy M. O'Neill

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To the College of Graduate Studies:

We are hereby submitting a Field Study written by Amy M. O'Neill entitled, "The Effects of STEM Integration on the Mathematics Achievement of Males and Females in Grades Three Through Eight" (Under the direction of DR. J. GARY STEWART). We have examined the final copy of this Field Study for form and content. We recommend that it be accepted in partial fulfillment of the requirements for the degree of Educational Specialist in School Administration and Leadership.

Dr. J. Gary Stewart, Research Committee Chairperson

Dr. John R. McConnell, Committee Member

Dr. Anthony R. Sanders, Committee Member

Accepted for the Graduate and Research Council:

Dean, College of Graduate Studies

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Amy M. O'Neill

Date May 2016

DEDICATION

I would like to dedicate this field study to my family. Most of all, I am so appreciative of my husband Matthew. He is my best friend, and has always been an ardent supporter of my personal and professional goals. Even when he was thousands of miles away in Afghanistan, he was whispering words of encouragement in my ear. I am so lucky to share this wonderful life with such an incredible man.

A special thank you also goes to my five children: Mae, Matthew Jr., Connor, Erin, and Brigid. There were so many times when I worked on my research at the expense of quality time with my sweet children. I can only hope that I am an example to each of them of the importance of lifelong learning.

This field study is also for my parents, Paul and Cydney Mullen, my first and most steadfast supporters. My mom constantly set an example of the pursuit of higher education, as well as the sacrifice involved in being both a professional educator and a mother. I am so grateful to her for the many long conversations we had about this research. My dad has always provided me with a listening ear and occasionally, a gentle push. I appreciate his generosity of spirit, his lighthearted sense of humor, and his interminable encouragement.

I am also extremely grateful for my parents-in-law, Mark and Rebecca O'Neill, for always telling me how proud they are, and for expressing awe at all I have tried to accomplish. I am so lucky to have two sets of parents that love me unconditionally.

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ABSTRACT

AMY M. O'NEILL. "The Effects of STEM Integration on the Mathematics Achievement of Males and Females in Grades Three Through Eight" (Under the direction of DR. J. GARY STEWART).

The purpose of this field study was to explore the possible effects of Science, Technology, Engineering, and Mathematics (STEM) on the Mathematics achievement of male and female students in the Clarksville-Montgomery County School System (CMCSS). This study utilized archival data from the years 2009 and 2013, and examined the Mathematics achievement of 25,844 students in grades three through eight in the Clarksville-Montgomery County School System (CMCSS). The researcher conducted a binary logistic regression analysis to determine the statistical significance of the Science, Technology, Engineering, and Mathematics (STEM) model of instruction on the Mathematics achievement of male and female students in grades three through eight.

This field study found that, overall, there was a statistically significant difference between the Mathematics achievement of students before and after the integration of Science, Technology, Engineering, and Mathematics (STEM) education in schools. This field study also found that there was a statistically significant difference between the Mathematics of male students versus female students after the integration of Science, Technology, Engineering, and Mathematics (STEM) education in schools.

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INTRODUCTION

Statement of the Problem

According to numerous sources, females are less likely than males to take higher level Mathematics and Science courses in high school and college. Subsequently, female students are also less likely to pursue careers in Mathematics-related and Science-related fields. Despite a long-held belief that females tend to demonstrate strength in Reading while males tend to be stronger in Mathematics and Science, current research indicates that in elementary and middle school, males and females are generally equally successful in Mathematics and Science, although females do tend to fall behind in Mathematics and Science as they get older.

In an effort to prepare students for success in college and careers, the Clarksville-Montgomery County School System (CMCSS) has recently incorporated Science, Technology, Engineering, and Mathematics (STEM) into all the elementary, middle, and high schools in the district. The Clarksville-Montgomery County School System (CMCSS) has also designated one high school as a Science, Technology, Engineering, and Mathematics (STEM) Career Academy, with the goal of specifically targeting students with an interest in Science, Technology, Engineering, and Mathematics (STEM) related education and career fields (Clarksville-Montgomery County School System, 2015). By integrating the Science, Technology, Engineering, and Mathematics (STEM) initiative in a way that is arguably unlike any other district in the state of Tennessee, the

Clarksville-Montgomery County School System (CMCSS) is hopeful that both male and female students in the district may demonstrate a high rate of success in Mathematics and Science during elementary and middle schools, as well as throughout high school and college.

Purpose of the Study

The purpose of this field study was to explore whether or not participation in the Science, Technology, Engineering, and Mathematics (STEM) program had an impact on the academic success of male and female students in Mathematics in grades three through eight, as measured by academic achievement on the Tennessee Comprehensive Assessment Program (TCAP) test. The independent variables for this study were the gender of participants and years of assessment, while the dependent variable was the academic achievement as measured by the Tennessee Comprehensive Assessment Program (TCAP) Mathematics scores.

Significance of the Study

The research collected from the data and the accompanying analyses of the data from this field study will help to determine if the implementation of the Clarksville-Montgomery County School System (CMCSS) Science, Technology, Engineering, and Mathematics (STEM) initiative had an effect on the academic achievement in Mathematics of male and female students in grades three through eight. Additionally, analyzing the data will help to determine if males and females were affected equally by the Science, Technology, Engineering, and Mathematics (STEM) initiative. As a result of this study and its accompanying analyses, the Clarksville-Montgomery County School System (CMCSS) administrators and Central Office personnel will be able to determine the benefits and challenges of the current implementation of the Science, Technology, Engineering, and Mathematics (STEM) initiative. The Clarksville-Montgomery County School System (CMCSS) Science, Technology, Engineering, and Mathematics (STEM) initiative may be revised as a result of this field study in order to facilitate greater academic success for all students in Mathematics. Teachers in the district will benefit from the research findings in this field study by gaining knowledge regarding whether or not Science, Technology, Engineering, and Mathematics (STEM) education leads to an increase in academic success for all students in Mathematics, and whether or not male and female students were affected equally. This understanding may lead to a shift in teaching practices or a change in the way instruction is differentiated for male and female students. Parents, students, and educators in the Clarksville-Montgomery County School System (CMCSS) will also benefit if the data show that participation in Science, Technology, Engineering, and Mathematics (STEM) education positively impacted academic success. Evidence supporting the Clarksville-Montgomery County School System (CMCSS) Science, Technology, Engineering, and Mathematics (STEM) program will lead to greater support from parents, students, community leaders, and other stakeholders. The anticipated community support could also lead to a larger number of students choosing to pursue careers in Science, Technology, Engineering, and Mathematics (STEM) related fields—an area of particular concern for females. Additionally, the findings in this field study may support the research of other educators in their own research studies.

Research Questions

The following Research Questions are appropriate to this field study:

1. Does the integration of Science, Technology, Engineering, and Mathematics (STEM) education have an impact on the academic achievement of male and female students in Mathematics in grades three through eight?
2. Does the integration of Science, Technology, Engineering, and Mathematics (STEM) education impact the academic achievement of male and female students equally in Mathematics?

Null Hypotheses

The following Null Hypotheses are appropriate to this particular field study:

1. There will be no statistically significant difference in the academic success of male and female students in Mathematics in grades three through eight before and after the implementation of Science, Technology, Engineering, and Mathematics (STEM).
2. There will be no statistically significant difference between the academic success of males and females in Mathematics before and after the implementation of Science, Technology, Engineering, and Mathematics (STEM).

Limitations

1. The first limitation in this study was that academic achievement was determined based on a single assessment. The Tennessee Comprehensive

Assessment Program (TCAP) was the only measure of achievement used in this study to determine academic success in Mathematics.

2. A second limitation in this study was that the Tennessee Comprehensive Assessment Program (TCAP) did not account for all variables that may affect student achievement. For example, it did not account for student anxiety, teacher effectiveness, socioeconomic status, race, or student interests and motivation.
3. A third limitation was that the study included the scores of every test taker in the district, without accounting for students who may have recently entered the Clarksville-Montgomery County School System (CMCSS), or students with disabilities.
4. The fourth limitation of this study was that data utilized for each sample were collected from one-year periods. More reliable results may be possible by utilizing data for each sample that is collected over the course of several years.

Assumptions

1. One assumption in this field study was that all students performed to the best of their abilities on the Tennessee Comprehensive Assessment Program (TCAP) test in the areas of Mathematics during the years 2009 and 2013.
2. A second assumption in this study was that a student's Mathematics performance on the Tennessee Comprehensive Assessment Program (TCAP) test was a result of the Science, Technology, Engineering, and Mathematics (STEM) initiative implemented by the Clarksville-Montgomery County School System (CMCSS) school district.

3. A third assumption of this field study was that the treatment of male and female students was equal in classrooms throughout the Clarksville-Montgomery County School System (CMCSS) school district.
4. Finally, this field study assumes that all teachers in the Clarksville-Montgomery County School System (CMCSS) school district have had the same Science, Technology, Engineering, and Mathematics (STEM) training and implement Science, Technology, Engineering, and Mathematics (STEM) instruction in the same way in all classrooms.

Definition of Terms

1. **Tennessee Comprehensive Assessment Program (TCAP):** A state required, standardized achievement test given to students in grades 3-8. Results are reported each fall in the state's annual Report Card (Tennessee Department of Education, 2015b).
2. **Science, Technology, Engineering, and Math (STEM):** A Mathematics and Science curriculum that also incorporates the use of Technology and concepts of Engineering in a hands-on and problem-based approach to learning (California STEM Learning Network, 2015).
3. **Tennessee Value-Added Assessment System (TVAAS):** A measurement of student growth utilized by the Tennessee Department of Education to determine the effectiveness of schools and teachers on the academic progress of a student (Tennessee Department of Education, 2016b).

CHAPTER II

REVIEW OF THE LITERATURE

Throughout the United States, people have suddenly become aware of the crisis in American education: too few high school students are graduating adequately prepared to continue on to college or pursue a career (Laboy-Rush, n.d.). It has become the belief of many policy-makers that students should spend more time and practice solving problems rather than simply memorizing facts while in school. Officials have demanded that students develop twenty-first century skills such as critical thinking, creativity, group collaboration, real-world problem solving, effective communication, and technological literacy. According to Laboy-Rush (n.d.), "curriculum and education reform efforts suggest that when students 'do science' they gain knowledge and skills that are transferrable to future problems and that help prepare them to approach college and careers with the tools to succeed" (p. 3). Numerous sources report that students' learning is the richest and most engaging when students are encouraged to develop their own understanding of the world around them. One instructional model that supports this type of creative learning is the integrated model of Science, Technology, Engineering, and Mathematics (STEM) education.

History of STEM

Although it is unclear exactly when the term "STEM" first emerged, modern references to Science, Technology, Engineering, and Mathematics as a part of a well-rounded curriculum were made as early as 1985 (Heltin, 2015). That date, however, is far too recent for many, who claim that the fundamental idea of an integrated

Mathematics and Science curriculum has been a part of American education since our country began.

In 1749, Benjamin Franklin published a pamphlet entitled *Proposals Relating to the Education of Youth in Pennsilvania* [*sic*]. In that work, Franklin expressed the desire for a group of wealthy individuals, whom he referred to as "Persons of Leisure and publick [*sic*] Spirit" (Franklin, 1749, p. 6) to establish an academy focused intently on the education of the youth of the time. According to Franklin (1749), the founders of this school would not only provide the funds required to sustain the school, but also participate in its functioning as actively as possible:

> That the Members of the Corporation make it their Pleasure, and in some Degree their Business, to visit the Academy often, encourage and countenance the Youth, countenance and assist the Masters, and by all Means in their Power advance the Usefulness and Reputation of the Design; that they look on the Students as in some Sort their Children, treat them with Familiarity and Affection, and when they have behav'd [*sic*] well, and gone through their Studies, and are to enter the World, zealously unite, and make all the Interest that can be made to establish them , whether in Business, Offices, Marriages, or any other Thing… (p. 7)

The structure of the school Franklin envisioned can be closely related to that of a modern boarding school, since Franklin suggested that the students live, work, and enjoy recreational activities on the campus. The curriculum at the school was also of concern to Franklin, and he stated that "As to their STUDIES, it would be well if they could be taught *every Thing* that is useful" (Franklin, 1749, p. 11). In particular, Franklin specified that the academy must be furnished with a library where students could investigate Mathematics, Science, and Engineering. He required that "the House be furnished with a Library…with Maps of all Countries, Globes, some mathematical Instruments, and Apparatus for Experiments in Natural Philosophy, and for Mechanics; Prints, of all Kinds, Prospects, Buildings, Machines, &c [*sic*]" (pp. 8-9). Without realizing it, Benjamin Franklin's ideal learning institution may very well be considered the United States' first Science, Technology, Engineering, and Mathematics (STEM) School.

The Ecole d'Arts et Métiers of Châlons-sur-Marne in northeastern France is also an important footnote in the history of Science, Technology, Engineering, and Mathematics (STEM) education. Although it was established in France rather than in the United States, Napoleon Bonaparte founded that school in 1803 as a way to prevent France from falling behind the British in industry. The premise of the school was to "train boys and young men in a more rational approach to production and send them out to lead industrial change" (Pannabecker, 2004, p. 222) through a curriculum that integrated disciplines such as forging, carpentry, and foundry as well as with the content areas in a traditional classroom of the time, such as Geometry, Drafting, Mathematics, and Science. Students at this unique school crafted numerous products, including furniture, clocks, textile machinery, and scientific instruments (Pannabecker, 2004). From 1808 to 1815, many of the older students at the school also developed and manufactured interchangeable parts for Napoleon's artillery, participating in a form of engineering that had never been seen before that time (Pannabecker, 2004).

In 1824, only a few years after the establishment of The Ecole d'Arts et Métiers of Châlons-sur-Marne, the Rensselaer Polytechnic Institute was founded in New York. The components of Science, Technology, Engineering, and Mathematics (STEM) were a part of the curriculum from the beginning, and are still prevalent at this institution, with degrees such as the B.S./M.D. Physician-Scientist Program, which is typically achieved in seven years, and the B.S./J.D. in Science, Technology and Society Law, which takes approximately six years to complete (U.S. News &World Report, 2016). This nation's oldest technological university, the Rensselaer Polytechnic Institute was established with the intent of bringing traditional principles of science to everyday life and is currently considered a highly ranked engineering program in the United States (U.S. News &World Report, 2016).

Following the establishment of the Rensselaer Polytechnic Institute was the Land Grant College Act of 1862, a federal statute that may have been the precursor to modern Science, Technology, Engineering, and Mathematics (STEM) academies. The Land Grant College Act of 1862 authorized each state in the United States 30,000 acres per congressional seat, an amount of land that was dedicated specifically for founding colleges that specialized in Agriculture and Mechanic arts (Land-Grant College Act of 1862, 2016). Also known as the Morrill Act because of its sponsor, a Vermont Congressman named Justin Smith Morrill (Land-Grant College Act of 1862, 2016), the Land Grant College Act was responsible for the establishment of numerous well-known institutions still in operation today. The Agricultural College of the State of Michigan was the nation's very first land-grant university. Known today as Michigan State University, it was established through a pre-Morrill Act allotment of 14,000 acres (Epsilon Sigma Phi National, n.d.). Shortly after Michigan State University was established, the Farmers' High School of Pennsylvania—now known as Pennsylvania

State University—was founded (Epsilon Sigma Phi National, n.d.). Other notable land-grant universities still in existence today are Iowa State University, Kansas State University, and Rutgers University (Epsilon Sigma Phi National, n.d.). The Agriculture and Mechanic arts aspect of the curriculum is responsible for the "A&M" designation still present in the names of many colleges and universities, such as Florida A&M University and Texas A&M University (Epsilon Sigma Phi National, n.d.). In addition to Agriculture and Mechanic arts, the Morrill Act of 1862 required that military tactics be included in the curriculum, which led to the Reserve Officers' Training Corps (ROTC), a military training program for commissioned officers in the Army, Navy, and Air Force (Land-Grant College Act of 1862, 2016).

Another major event in the history of Science, Technology, Engineering, and Mathematics (STEM) would not occur for quite some time, but seventy-seven years after the Land Grant College Act of 1862, Germany invaded Poland and the Second World War began. Although the United States remained absent from the war until the bombing of Pearl Harbor in 1941, nearly 417,000 service members had lost their lives by the end of the conflict (The National WWII Museum, n.d.), and the conflict impacted the United States in several major ways. For example, two of the most significant weapons in world history were developed during this time: the atomic bomb and penicillin. Penicillin was discovered, quite by accident, in 1929 by a bacteriologist named Sir Alexander Fleming. Sir Fleming left a plate of bacteria uncovered, only to return quite some time later and discover that a mold that had developed on the bacteria had actually killed much of it (History, 2010). On February 14, 1929, Fleming introduced the mold by-product, which he called penicillin, as a means to fight bacterial infections (History, 2010). According to

Oatman (2005), penicillin was the most important weapon developed during World War II. He stated that "along with the microbial drugs that came afterwards, it lowered the incidence and severity of infectious diseases and made medical advances such as burn management, open-heart surgery, and organ transplantation possible" (Oatman, 2005, para. 24).

The atomic bomb was another crucially important scientific development during World War II. Many scientists at the time suspected the effect of the atomic bomb on the enemy, but few could have ever imagined the true devastation it held. The United States dropped the first of two atomic bombs on the Japanese city of Hiroshima on August 6, 1945 and another on the city of Nagasaki three days later (History, 2009). The explosion in Hiroshima destroyed approximately ninety percent of the city, and caused the immediate death of 80,000 people. Tens of thousands more Japanese would later die due to radiation exposure from the bomb (History, 2009). Nagasaki's devastation was massively tragic as well, killing an estimated 40,000 people. Shortly after the bombing of Hiroshima and Nagasaki, Japan's Emperor Hirohito announced the unconditional surrender of the Japanese on August 15, 1945, referring to the brutal power of "a new and most cruel bomb" (History, 2009, para. 1).

After the end of World War II, many Americans realized that penicillin and the atomic bomb were only the two best known of a plethora of contributions made by the research community at that time, and that scientists and engineers had played a pivotal role in helping the United States win the war (National Science Foundation, 2016). With the war now behind them, politicians and researchers had to ensure that even during times of peace, Science and Engineering would "continue both to expand the frontiers of knowledge and serve the American people" (National Science Foundation, 2016, para. 1). In an effort to continue this advancement of Science and its related disciplines, the National Science Foundation (NSF) was established in 1950. One of the most significant moves towards the modern idea of a true Science, Technology, Engineering, and Mathematics (STEM) integration, the National Science Foundation (NSF) is the only federal agency dedicated to research and education in all Science and Engineering disciplines, and to ensuring that the United States remains a leader in scientific discoveries and new technology. They also continue to remain actively involved in education programs and in the scientific research community (National Science Foundation, 2016).

As the United States began to focus on the importance of intertwining the disciplines in Science, Technology, Engineering, and Mathematics (STEM), so did the rest of the world. The development of our current idea of a focus on Science, Technology, Engineering, and Mathematics (STEM) is often credited to the Russian launch of the world's first artificial satellite, Sputnik I, in October of 1957 (Bybee, 2013; Woodruff, 2013). According to NASA (2007), "That launch ushered in new political, military, technological, and scientific developments. While the Sputnik launch was a single event, it marked the start of the space age and the U.S.-U.S.S.R space race" (para. 1). The successful launch of Sputnik I was actually the first of five Sputnik missions, and it shocked the world. The United States, in particular, was caught off-guard, and the federal government immediately began looking for ways to ensure that the United States did not fall behind in what would soon be referred to as the Space Race (NASA, 2007).

In the late 1950s, the National Science Foundation (NSF) began funding summer programs for Mathematics and Science teachers, possibly as a response to the Russian launch of the satellite, Sputnik. But funding for teachers did not seem to be enough. Lolly (2009) stated that:

> The United States' reaction to the launch of Sputnik, coupled with an already ongoing criticism of the American educational system, set the stage for an unprecedented infusion of funding from the federal government to reform public education at all levels. (p. 50)

This influx of money for the education system came when the National Defense Education Act (NDEA) was passed in September of 1958. A law that provided $1 billion in additional funding over the next four years, the National Defense Education Act was primarily aimed at supporting the education of students pursuing degrees related to the fields of Science, Technology, Engineering, and Mathematics (STEM) (Lolly, 2009).

The National Defense Education Act (NDEA) was quickly followed by another important piece of legislation, known as the Space Act. Enacted in October of 1958, the Space Act was responsible for the creation of the National Aeronautics and Space Administration (NASA) (NASA, 2007). Over the next several decades, the United States government continued to focus on the importance of Science, Technology, Engineering, and Mathematics (STEM) in education, even though that particular acronym had not yet been thought of. In 1983, a report on the status of education titled *A Nation at Risk* was released by the National Commission on Excellence in Education. This report was not the first criticism of the American educational system, but even today, it is often considered the most alarming (Khadaroo, 2013). The report stressed the importance of re-energizing the nation's educational system, claiming that the United States was falling behind other countries due to "a rising tide of mediocrity that threatens our very future as a Nation and a people" (United States National Commission on Excellence in Education, 1983, para. 2). In particular, the report mentioned the former superiority of the United States in commerce, industry, science, and technological innovation, and claimed that:

> If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war. As it stands, we have allowed this to happen to ourselves. (United States National Commission on Excellence in Education, 1983, para. 3)

Similar to the Space Race of the 1950s and 1960s, the United States was involved at the time in a nuclear arms race with other nations—particularly the Soviet Union. For those who remembered the effect of the Sputnik launch on the United States, *A Nation at Risk* seemed to use that same familiar language to incite a sense of urgency for change:

> We have even squandered the gains in student achievement made in the wake of the Sputnik challenge. Moreover, we have dismantled essential support systems which helped make those gains possible. We have, in effect, been committing an act of unthinking, unilateral educational disarmament. (United States National Commission on Excellence in Education, 1983, para. 3)

In its recommendations, *A Nation at Risk* challenged educational institutions to implement higher expectations for academics as well as student conduct, and—most importantly—to adopt more rigorous and measurable standards of achievement. The report named five specific content areas, referred to as the Five New Basics that it believed schools should focus on: English, Mathematics, Science, Social Studies, and Computer Science (United States National Commission on Excellence in Education, 1983). With the exception of an Engineering component, the fundamental concepts of Science, Technology, Engineering, and Mathematics (STEM) are all present in *A Nation at Risk*. The report specifically asserted the importance of applying Mathematics and Science in the real-world, as well as utilizing Technology for personal and professional purposes, claiming that the foundation provided by a solid understanding of the Five New Basics was necessary for success later in life (United States National Commission on Excellence in Education, 1983).

Several years after A Nation at Risk was published, in July of 2000, then-governor George W. Bush developed a plan to allocate "$345 million to increase federal student-loan forgiveness for students who major in science, math, technology, or engineering and commit to teach in a high-need school for at least five years" (Heltin, 2015, para. 6). Around the same time, Judith A. Ramaley, the Assistant Director for Education and Human Resources at the National Science Foundation from 2001 to 2004, developed an integrated curriculum for Science, Mathematics, Engineering, and Technology with her team. Although Ramaley and her team referred to this curriculum as "SMET", they reportedly did not like the term, and decided to change it (Heltin, 2015). There is no specific mention of the term "STEM" at this time, however, so it seems as if the first deliberate use of the phrase Science, Technology, Engineering, and Mathematics (STEM) and its accompanying acronym "STEM" may have been in 2005 by Representative Vernon Ehlers of Michigan, and Representative Mark Udall of Colorado when they established the Science, Technology, Engineering, and Mathematics (STEM) Education Caucus for Members in Congress, a caucus that still exists today (Heltin, 2015). Even though its exact origins may be somewhat unclear, Science, Technology, Engineering, and Mathematics (STEM) has become a well-known term and integrated curriculum that is frequently used in education in the United States.

The STEM Classroom

The Science, Technology, Engineering, and Mathematics (STEM) instructional model demands the deliberate integration of Science, Technology, Engineering, and Mathematics in the classroom. Rather than teaching Mathematics and Science in isolation—pretending that one content area has nothing to do with the other— the core of Science, Technology, Engineering, and Mathematics (STEM) revolves around the idea that the two traditional content areas of Mathematics and Science, as well as Engineering concepts and the application of Technology, are best taught in conjunction with one another. According to one Johnson (2014):

> We have gone about as far as we can go with isolated instruction and learning. While it may have served the purpose for the older generations, it does not meet the deeper learning needs of the students of today and tomorrow. (p. 1)

Current Methodology

Unfortunately, the idea of total integration pertinent to implementing Science, Technology, Engineering, and Mathematics (STEM) is not really supported by current teaching methodology. Educators today are under enormous pressure to produce students who can perform magnificently on end-of-year standardized tests. In fact, many educators receive ratings, job security, and even bonuses based on their students' performance on these assessments. This intense focus on test performance conflicts with the heart of Science, Technology, Engineering, and Mathematics (STEM). Rather than allowing students to explore concepts independently and make their own connections between Mathematics, Science, and the real-world, students are expected to fill in bubbles or blanks on a standardized test based on memorized content. Since this method is the way students are tested, teachers are often trapped into trying to teach students in this way, too. Consequently, the focus of education is often on the product, rather than the process. Under the current method, teachers are the holders of the knowledge, and students are the receivers of that knowledge. A popular method currently in education is what is known as the gradual release model, often referred to by teachers as "I do, we do, you do" (Levy, 2007, p. 1). This model requires that a teacher first demonstrate a skill for the class. Next, the class will practice it together, and then, students will practice the skill independently, with teacher support.

The Science, Technology, Engineering, and Mathematics (STEM) instructional model, on the other hand, is more about the process of learning, rather than the product. Although students are still expected to learn specific content standards, the method of learning that content is very different than the traditional gradual release model. In a Science, Technology, Engineering, and Mathematics (STEM) classroom, 'I do, we do, you do' is reversed to become 'you do, we do, I do'. This model requires that the student drive the instruction, with the teacher in a supporting role, guiding students towards the concepts they need to know. The emphasis in a Science, Technology, Engineering, and Mathematics (STEM) classroom is on creating learning opportunities that allow students to discover what they need to know, while encouraging creativity and problem-solving along the way. In this type of classroom, there is an emphasis on perseverance and curiosity, and students are encouraged to figure things out for themselves based on trial and error, rather than being told what to solve and how to solve it. This method is necessary in order to prepare students to think critically and problem-solve in a world inundated with technology. In fact, regardless of what career path students choose, chances are they will be required to interact with technology in some way or another. According to an action plan release by the National Science Foundation (2007):

> …the Nation is failing to meet the STEM education needs of U.S. students, with serious implications for our scientific and engineering workforce in the 21st century. Addressing this issue is absolutely essential for the continued economic success of the Nation and its national security. All American citizens must have the basic scientific, technological, and mathematical knowledge to make informed personal choices, to be educated voters, and to thrive in the increasingly technological global marketplace. (p. v)

Challenges of Implementation

Although the Science, Technology, Engineering, and Mathematics (STEM) model of instruction may appear to be an incredible method of instruction, many educators struggle to teach students with this model (Davis, 2014). In addition to the obvious hurdle of standardized testing, there are many other barriers to a Science, Technology, Engineering, and Mathematics (STEM) centered classroom. First, many teachers are unfamiliar with how to teach the way that Science, Technology, Engineering, and Mathematics (STEM) is supposed be taught. Educational licenses are usually non-grade specific, and many teachers are licensed to teach all subjects in a wide range of grades. Some teachers, for example, can be certified in Kindergarten through sixth grades, while others may be certified to teach Kindergarten through eighth grades, depending on the specific college or university attended by the educator, as well as the licensing state. Since most education licenses for Kindergarten through eighth grades do not specify the content area or areas in which a teacher can instruct, many colleges and universities still emphasize traditional methods of instruction in teacher preparatory courses. The result is that many teachers often enter the classroom without any knowledge or practice in instructional strategies that should be used in Science, Technology, Engineering, and Mathematics (STEM). Unless teachers receive instruction through their school or district, or unless they are able to find the time and resources to teach themselves what Science, Technology, Engineering, and Mathematics (STEM) instruction looks like, teachers tend to stick to what they know, which is the traditional approach to teaching. This reluctance to implementing Science, Technology, Engineering, and Mathematics (STEM) equates to a lack of buy-in for teachers, parents, students, and other stakeholders.

In Maryland, in 2009, the Science, Technology, Engineering, and Mathematics (STEM) Task Force reporting to then-Governor Martin O'Malley issued a report that urban and rural school districts were having a difficult time not only recruiting highly qualified Mathematics and Science teachers, but also retaining them (Davis, 2014). The report stated that "According to national data, that annual turnover of Mathematics teachers is 16.4 percent, the highest of all content areas, and 15.6 percent in Science" (Davis, 2014, para. 11). The recommendation given by Governor O'Malley's task force was to triple the number of teachers in Science, Technology, Engineering, and Mathematics (STEM) and enhance the Science, Technology, Engineering, and Mathematics (STEM) preparation and skill level for teachers (Davis, 2014). As a response to those recommendations, Carroll County Public Schools (CCPS), a large school district near Baltimore, Maryland, teamed up with a local college, McDaniel College, to create a Science, Technology, Engineering, and Mathematics (STEM) program that would help educators who wanted to specialize in Science, Technology, Engineering, and Mathematics (STEM) education (Davis, 2014). Although it continues to be a successful teacher preparation program to this day, this type of program is not currently the norm in teacher education.

Another barrier to Science, Technology, Engineering, and Mathematics (STEM) instruction is that it is extremely time-consuming to allow students to drive instruction. It might take several days for a lesson, or a few weeks to complete a big project—a luxury that many teachers believe they do not have. While working on a Science, Technology, Engineering, and Mathematics (STEM) project, teachers must be constantly aware of the scope and sequence of instruction provided by the school system. Admittedly, it can be very difficult to stay on a schedule while teaching in a Science, Technology, Engineering, and Mathematics (STEM) classroom. Since the students drive learning in this type of environment, it is nearly impossible to pinpoint exactly all of the standards that are being addressed, and when the learning of specific content may be complete. What many fail to understand, however, is that although a particular Science, Technology, Engineering, and Mathematics (STEM) project may take several days or even weeks to complete, the learning is rich and the students are engaged. It is also possible to incorporate many more standards into one Science, Technology, Engineering, and Mathematics (STEM) project than could be covered in the same amount of time using traditional teaching methods.

A third barrier to implementing Science, Technology, Engineering, and Mathematics (STEM) instruction is—ironically—a byproduct of the technological age students live in. With the constant reinforcement of instant gratification through websites, apps, and the plethora of other forms of technology, people have simply grown impatient with waiting for anything (Muther, 2013). Students today are growing up in a world bombarded by technology. The result of all this technology is that people—children especially—have become immersed in what Muther (2013) referred to as "hyperconnected lives" (para. 4). According to Muther (2013), the Pew Research Center's Internet & American Life Project conducted a study about the current inundation of technology and found that "negative effects include a need for instant gratification and loss of patience" (para. 4). As a result of the overwhelming use of technology, students have become so soothed by instant gratification that they are beginning to develop frustration with irresolution. Simply put, children today often struggle with persevering: they expect easy solutions to all problems, and are frustrated when things aren't resolved immediately. The Science, Technology, Engineering, and Mathematics (STEM) model of instruction, however, requires that students figure things out on their own by testing hypotheses, building a system, or imagining a solution. This process is crucial to establishing critical thinking and problem-solving skills, and short-changing this process is tantamount to cheating a student out of the benefits of a Science, Technology, Engineering, and Mathematics (STEM) centered experience. The tendency of our society to lean towards quick solutions and instant gratification is one way that the Science, Technology, Engineering, and Mathematics (STEM) method can be interrupted, compromising the benefits of developing critical thinking skills, creativity, and ingenuity.

Despite these barriers, however, there are several current trends that are a positive force for implementing Science, Technology, Engineering, and Mathematics (STEM) in the classroom. For example, one of the tenets of Science, Technology, Engineering, and Mathematics (STEM) is the integration of multiple content areas. Rather than teaching each subject in isolation, the Science, Technology, Engineering, and Mathematics (STEM) model of instruction requires that each subject should be taught in conjunction with the others. This idea of cross-curricular instruction is not a new concept in education. In fact, the National Council of Teachers of English (NCTE) discussed an integrated curriculum as early as 1935, when it suggested that subjects could be integrated with one another in multiple ways:

> Correlation may be as slight as casual attention to related materials in other subject areas . . . a bit more intense when teachers plan it to make the materials of one subject interpret the problems or topics of another. (Drake & Burns, 2004, para. 7)

Therefore, implementing Science, Technology, Engineering, and Mathematics (STEM) in the classroom requires that teachers integrate several subjects into their lessons—an idea that has been around for decades and is at least familiar to teachers.

Another positive trend that supports Science, Technology, Engineering, and Mathematics (STEM) in the classroom is that focusing on hands-on learning experiences and utilizing technology both increase student motivation and engagement. In fact, research has continuously shown that regardless of what type of technology is utilized in the classroom, the effect on students that was most commonly reported was an increase in motivation (Gardner, 2011). The fact is, children love to explore and discover learning in ways that they perceive as fun. Reading from a text and filling out worksheets for several hours a day can be boring for students, and when motivation decreases, so do test scores: "students who are bored or inattentive or who put little effort to schoolwork are unlikely to benefit from better standards, curriculum, and instruction" (Crotty, 2013, para. 4). Science, Technology, Engineering, and Mathematics (STEM), on the other hand, can be loud, messy, and creative. Students participate in hands-on learning, which they often perceive as play. Due to the Engineering component of Science, Technology, Engineering, and Mathematics (STEM), students also imagine, draw, create, build, and destroy things in the classroom. This kind of hands-on learning can be extremely motivating to students, and that increase in motivation can often lead to increased learning, and then increased student achievement scores on standardized tests.

In brief, in order for students to develop the kinds of skills necessary for success in a technologically-driven global economy, it may be necessary for teachers to incorporate Science, Technology, Engineering, and Mathematics (STEM) into the classroom. Even though most standardized testing does not assess the kind of learning that Science, Technology, Engineering, and Mathematics (STEM) promotes, it is still possible for teachers to use a Science, Technology, Engineering, and Mathematics (STEM) methodology while at the same time focusing purposefully on Mathematics and Science standards to support growth and high achievement on standardized tests. It is possible, however, that education may not see the shift towards a true full Science, Technology, Engineering, and Mathematics (STEM) implementation until standardized testing changes or is removed altogether. In the meantime, it is important to promote the benefits of Science, Technology, Engineering, and Mathematics (STEM) by encouraging students to think critically about real-world problems by incorporating these types of scenarios into classroom learning every day.

The Changing World

In this increasingly global economy, children today are growing up in a world unlike anything their parents or grandparents could have possibly imagined. On a daily basis, children are bombarded with a staggering amount of technology. Many wake up to alarms on their cell phones, scroll through a newsfeed as they eat breakfast, and learn and study by playing with apps on a smartphone. It follows, then, that since the world in which students live is changing, the way they are educated should likewise change. In an effort to address the surge of technology in today's world, to support the integration of Mathematics and Science, and perhaps to encourage students to pursue careers in Mathematics-related and Science-related fields, many school districts have implemented Science, Technology, Engineering, and Mathematics (STEM) programs in their schools.

The question that therefore emerges is whether there is really any substantial evidence that Science, Technology, Engineering, and Mathematics (STEM) programs lead to higher student achievement in Mathematics or Science. If so, does Science, Technology, Engineering, and Mathematics (STEM) education impact the academic achievement of male and female students equally?

Beliefs Concerning Gender Ability

For many years, it was believed that male students were good at Mathematics and female students were good at Reading. This popular belief seems to come from the fact that numerous studies conducted over nearly the last half-century have documented the superior language abilities of female students (Swaminathan, 2008). According to the research, the documented higher achievement scores in Reading for female students were linked to the way words are processed by the brain. While completing linguistic tasks, female students showed increased activity in the part of the brain dedicated to language encoding, which helps to decipher information abstractly. In contrast, the male students showed increased activity in the parts of the brain related to visual and auditory functions, depending on the way words were presented (Swaminathan, 2008). Therefore, although male and female students tended to be equally capable of success in Reading, the research implied that male students needed to have language presented visually *and* orally in order to experience the greatest success. Conversely, female students were capable of success with either presentation venue (Swaminathan, 2008). As a result, the societal belief for numerous years was that female students were good at Reading—which many believed meant they were therefore bad at Mathematics.

Over time, however, many researchers and educators began questioning these long-held beliefs. Throughout the 1970s and 1980s, there were numerous studies conducted on the connections between gender and achievement in Mathematics and Reading. Eventually, research revealed that, in fact, female students were not worse at Mathematics than male students. Actually, what the research showed was that there was very little difference in the achievement of male and female students in Mathematics and Science. However, it would take several more years and extensive research before these research studies and their postulates would reach popular culture. Even after years of extensive research and overwhelming evidence to the contrary, many people still believe that when it comes to Mathematics, female students are still weaker than their male counterparts.

In July of 1992, the toy titan Mattel, Inc. released a toy called Teen Talk Barbie, and instead of rave reviews, they promptly received harsh criticism. A new version of a classic and beloved toy, Teen Talk Barbie contained a computer chip that randomly selected four verbal phrases out of a possible 270. One of the talking doll's phrases was "Math class is tough!" (Greene, 1992, para. 10). When Barbie uttered those words, the American Association of University Women, a national women's group, were highly critical of what they believed to be an offensive remark (The New York Times, 1992). The American Association of University Women claimed that schools were already shortchanging female students. Many other groups and media sources quickly followed suit by condemning the statement. Although Mattel, Inc. did not recall the toy—opting instead to offer to exchange the old doll for a newer version that did not speak at all—the company's president did admit that Mattel Inc. "didn't fully consider the potentially negative implications of the phrase" (The New York Times, 1992, para. 6).

Even before the Teen Talk Barbie debacle, there was sufficient evidence to discredit the old belief that male students were better at Mathematics. In 1973, the first long-term assessment by the National Assessment of Educational Progress (NAEP) indicated that 9-year-old and 13-year-old female students actually performed better than their male counterparts in Mathematics—and females would continue to do so throughout the rest of the 1970s (Mead, 2006). During the 1980s and 1990s, however, educators across the United States turned their attention towards a heavy focus on Mathematics instruction. As a result, all 9-year-olds and 13-year-olds improved in Mathematics achievement on the National Assessment of Educational Progress (NAEP). During this time of improvement, male students pulled very slightly ahead of females, leading to the very small gender gap in Mathematics achievement that currently exists. However, even though the data imply that male students currently outperform females in Mathematics and Science by a very small amount, there is actually a larger achievement gap between male and female students in geography—and yet, very little, if any, attention is paid to this fact (Mead, 2006).

In recent years, numerous researchers have continued to present evidence that discredits the archaic belief that male students are good at Mathematics and female students are good at Reading. Yet, owing to the plethora of factors that influence school performance—including biology, culture, development, and even motivation—it has been incredibly difficult to attribute success or failure to any one factor. Instead, differences in the achievement between male and female students have been attributed more to factors such as socioeconomic status and race, rather than gender. Mead (2006) offered the widely-accepted explanation that "low-income, minority, and female people consistently fall short of their affluent, white, and male peers" (Mead, 2006, p. 14). But challenging the gender question has continued to be difficult, especially given the well-documented absence of females from Science, Technology, Engineering, and Mathematics (STEM) related careers that require strength in Mathematics and Science. In fact, Dillon and Rimer, as cited in Berube and Glanz (2008), described a harshly-criticized statement that the achievement of males and females is hardwired. In 2005, the president of Harvard University declared that "the biological differences between men and women account for why women don't succeed in Math and Science careers" (as cited in Berube & Glanz, 2008, p. 30). This statement, made by the president of a highly respected academic institution, demonstrated that even into the twenty-first century, gender stereotypes in Science, Technology, Engineering, and Mathematics (STEM) are still perpetuated by those in positions of authority.

Research Findings on Achievement

Not surprisingly, the truth about female achievement in Mathematics and Science is much more complicated than what many previously thought. Current research indicates that, in actuality, male and female students tend to perform about the same on measures of achievement in Mathematics and Science:

> Historically, males have been reported to have higher levels of math achievement than females, but results of achievement tests given to elementary and high school

> students in the United States indicate that this gender gap has closed in recent years. (Gunderson, Ramirez, Levine, & Beilock, 2011, p. 153)

The traditionally held belief was that males had a natural affinity for Mathematics. However, that theory has been debunked over and over. Cheryan (2011) spoke definitively on the subject when she stated that "there is no longer any difference in standardized test scores in math between boys and girls all the way through high school" (p. 184). In 1983, the ratio of males to females was 13 males for every one female student in the top 10,000 students in Mathematics. By 2007, however, the ratio had decreased to between 2.8 and 4.0 boys for every girl (Azar, 2010). Had these gender differences been the result of some biological factor, it is unlikely that this shift would have occurred. These data are a clear indication that this particular shift towards female success in Mathematics is owed in large part to some other factor.

Career Choices for Females

Even though studies have clearly indicated that there are no significant differences between male and female performance in Mathematics from elementary school all the way through college (Chang, 2013), the fact remains that younger female students generally believe that their Science, Technology, Engineering, and Mathematics (STEM) abilities are just not as strong as those of their male counterparts (Sage Publications, 2013). In fact, Smeding (2012) explained quite clearly the damaging effect that stereotypes can have on females. Smeding (2012) stated that "...gender-STEM stereotypes have the potential to undermine girls' and women's self-perceptions of ability, performance and interest in...counter-stereotypic (masculine) disciplines" (p. 617). This belief in gender-STEM stereotypes might be part of the reason why women are simply not pursuing careers in Mathematics and Science at the same rate as men. In Computer Science and Engineering, for example, women earn fewer than 25% of the undergraduate and graduate degrees in the United States and hold less than one-third of all information technology jobs (Cheryan, 2011).

Interestingly, some Mathematics and Science career fields show very little difference between the numbers of degrees awarded to males and females, while others have significant disparities. In Psychology, for example, women earned 77.8% of the Baccalaureate degrees, 78.1% of Masters degrees, and 67.3% of Doctorates awarded between 1996-2004 (Halpern, Aronson, Reimer, Simpkins, Star, & Wentzel, 2007, p. 3), an overwhelming majority of degrees in that field. Women also dominated the number of degrees awarded in biological sciences in those years: 62.5% of the Baccalaureate degrees, 58.6% of the Masters degrees, and 46.3% of the Doctorates. In Mathematics, however, the numbers began to dip, with only 45.9% of the Baccalaureate degrees and 45.4% of the Masters degrees awarded to women. Doctorates awarded to women in Mathematics were a dismal 28.4% (Halpern, et al., 2007). Although the number of degrees awarded to males and females were nearly equally distributed in some areas, females were significantly underrepresented in other areas. In the field of Computer Science, for example, only a fourth of the Baccalaureate degrees were awarded to females, and in Engineering, the numbers were even lower: 20.5% of the Baccalaureate degrees (Halpern, et al., 2007).

If female students are just as capable as their male counterparts of demonstrating success in Science, Technology, Engineering, and Mathematics (STEM) related fields, why are female students not choosing to pursue careers in those areas? There is evidence to support the idea that this career selection gap is, in part, due to the fact that female students are more likely to lose confidence in their Mathematics abilities as they get older, and subsequently lose interest in higher level Mathematics and Science courses beginning in middle school (Berube & Glanz, 2008). Since female students take fewer higher-level Mathematics and Science courses as they get older, they are often not in a position academically to pursue careers that would utilize those skills. Clearly, something was—and is—influencing the career choices of female students. The question becomes, then, why are females not enrolling in more difficult Mathematics and Science classes?

Influences at Home

It is difficult to pinpoint any one specific reason why female students tend to not pursue higher-level Mathematics and Science courses and careers, even with the inclusion of Science, Technology, Engineering, and Mathematics (STEM) education in schools. It is clear, however, that part of the problem may begin at home, with parenting styles, traditions, and influences. According to Chang (2013), children are socialized differently regarding Mathematics based on their gender: males tend to receive more encouragement in Mathematics from both parents and teachers, and mothers often overestimate their sons' Mathematics abilities compared to their daughters' abilities. Chang cited further evidence of bias by parents: at an interactive exhibit at a science museum, parents engaged in discussion of scientific concepts to male children three times more often than to female children. Even gifts tend to be biased: males are much more likely to receive toys that promote Science, Technology, Engineering, and Mathematics (STEM) skills such as building and spatial reasoning than females (Chang, 2013). Surprisingly, the way that parents speak to their children is not immune to this Mathematical bias, either. When analyzing the conversations that mothers have with their toddlers, it was discovered that mothers discuss mathematics concepts and quantities with males three times more often than with their female children:

> For example, phrases such as 'he has two eyes' or 'How many feet do you have?' appeared nearly three times more in mother-son conversations than mother-daughter ones. In line with previous work on gender socialization, the greater confidence that boys show by early elementary school might be influenced by early experiences at home with their parents. (Chang, 2013, para 4)

Indeed, it seems that even though educators are attempting to even the playing field by including Science, Technology, Engineering, and Mathematics (STEM) in schools, stereotyped beliefs about Mathematics abilities in males versus females are alive and well at home. According to Gunderson et al. (2011), "parents have gender-stereotyped beliefs about their boys' and girls' math abilities even when boys' and girls' math achievement levels do not differ according to objective measures" (p. 155). Additionally, parents believe that females have to work harder than males in order to succeed in Mathematics, and mothers are more likely to base a son's success in Mathematics on natural talent, while a daughter's success is often attributed to hard work (Gunderson et al., 2011). Even something as simple as helping a child with homework can have unintended psychological consequences. Bhanot and Jovanovic (2005) stated that "when parents endorse particular academic gender stereotypes, they are more likely to engage in uninvited intrusions with homework, intrusions which then undermine children's confidence in these domains" (p. 597). If, for example, parents perceive that a daughter is struggling in Mathematics—regardless of whether she actually is or not—and subsequently participate in unsolicited intrusions into their daughter's homework, these actions will negatively affect the daughter's confidence in Mathematics. Further complicating the issue of confidence in Mathematics is the fact that the beliefs that mothers hold about their children's abilities are an even stronger predictor of the child's own beliefs than evidence such as actual grades (Leaper, Farkas, & Brown, 2012). Additionally, mothers have a greater influence on their children's beliefs about their abilities than do fathers, and since children tend to look to same-gender parents for cues regarding what is appropriate for that gender, this can be particularly influential for daughters, who are already strongly influenced by their mothers (Leaper, Farkas, & Brown, 2012). Through their words, actions, and even their own life choices, many mothers perpetuate the widely-accepted female gender role that directs women towards being communal by helping others, having a family, and raising children (Cheryan, 2011). Consequently, women are more likely to value careers that support these roles and less likely than men to enter careers that seem to conflict with these aims (Cheryan, 2011). The ramifications of these beliefs, unfortunately, seem to be that fewer women than men enter Science, Technology, Engineering, and Mathematics (STEM) related career fields:

> Math-related careers are perceived as less compatible with communal goals than other traditionally male-dominated careers, such as being a

> physician or a lawyer. This is unfortunate because stereotypes of math-related careers are largely inaccurate. Many in math-related careers such as computer science and engineering argue that their fields are fundamentally about helping society and involve frequent collaborations with others. (Cheryan, 2011, p. 186)

This same belief towards fulfilling communal goals may be the reason why some Mathematics-related and Science-related fields—such as medicine—see higher rates of women than other fields, such as Computer Science. Medicine, at its core, is about helping others—an acceptable pursuit for females who agree with the belief that women should fulfill communal roles. A field such as Computer Science, on the other hand, tends to be associated with fewer interpersonal interactions, which may be why females are less likely to pursue careers in this field.

Influences at School

Another reason for the lack of females in Science, Technology, Engineering, and Mathematics (STEM) related career fields might be the significant role that teachers play in the lives of their young female students. As young as preschool age, children are susceptible to gender stereotypes in Mathematics, and anxieties about spatial activities have been found to be more prevalent among female students than male students in first and second grades (Gunderson et al., 2011). Additionally, children are especially likely to accept Mathematics-gender stereotypes once they reach a period referred to as the 'peak stage of gender rigidity', which occurs in early elementary school. By this time, students have developed strong beliefs regarding which traits and activities are appropriate only for females or only for males (Gunderson et al., 2011). This crucial time of development often occurs in younger grades, before male and female students have even been presented with opportunities to discover their own individual talents and interests. Consequently, both male and female students may unknowingly conform to traditional academic stereotypes before they have even explored other possibilities. The strong influence of academic stereotypes on students is one reason why many educators are hopeful that the integration of Science, Technology, Engineering, and Mathematics (STEM) education at all grade levels—especially in elementary school—may help increase student achievement, but particularly the achievement of females in Mathematics.

There is also evidence that indicates that not only are elementary age children highly influenced by the adults in their lives, but that they are even more strongly influenced by adults of the same gender (The University of Chicago, 2010). Since more than 90% of elementary school teachers are female, and research indicates that elementary education majors have greater anxiety about Mathematics than any other major (Azar, 2010), female teachers with anxiety about Mathematics may negatively impact the Mathematics self-confidence of their female students. It is curious that male students do not seem to be affected by their female teachers' anxieties about Mathematics, but research does in fact indicate that a teacher's anxiety about Mathematics negatively affects females, rather than males (The University of Chicago, 2010).

Furthermore, in elementary schools, teachers tend to attribute the success of male students in Mathematics to ability, while they simultaneously attribute the female students' success equally to ability and effort. The problem with this presumption is that it leads to the idea that when a male student fails in Mathematics, it is because of a lack of effort—not working hard enough—which male students can presumably overcome simply by studying more and trying harder. For female students, however, teachers tend to believe that failure is due to a lack of ability—that females are simply not smart enough or unable to understand mathematical concepts—which, unfortunately, cannot be remedied no matter how hard a child studies (Gunderson et al., 2011).

Even something as simple as the verbal messages presented by the teacher in the classroom can affect a student's self-concept. According to Gunderson et al. (2011), the more positive messages students received about nonacademic behaviors, the less likely it was that they believed positive messages about academic behaviors. Conversely, the more criticism students received about nonacademic behaviors, the less likely those students were to believe negative messages about their academic behaviors. Teachers tend to praise female students more for nonacademic performance, such as neatness and kindness to others, which devalued the academic praise those teachers gave to their female students. Male students, however, received more criticism on nonacademic performance, which devalued the academic criticism they received. This may lead to male students attributing their own failures to a lack of effort, while female students may attribute their failures to a lack of ability (Gunderson et al., 2011). Dweck (2006) also examined the effects that verbal messages in the classroom have upon a student's beliefs about their Mathematics ability. In that study, researchers compared the Mathematics achievement of two groups. The first group was given the message that Mathematics ability was a gift that students were born with, and the other group was told that

Mathematics ability could be developed. The result was that the group that received messages that Mathematics ability could be developed performed better than those who were told their Mathematics abilities were fixed. The surprising effect, however, was that while male students did slightly better when they were told that Mathematics ability could be developed, when *female* students were given that same message, they outperformed their female counterparts in the other group by a significant margin (Dweck, 2006). In addition, Dweck also found that by the end of the eighth grade, an achievement gap between males and females in Mathematics performance only existed for students who believed that Mathematics abilities were a gift, giving support to the idea that the messages we send in education really do matter, and through them, we can help students—particularly female students—achieve their full potential as learners (Dweck, 2006).

Teachers' attitudes towards Mathematics have been shown to affect instructional techniques and the way they organize the content. Subsequently, student attitudes towards the subject often reflected that of their teachers (Gunderson et al., 2011). Teachers with low Mathematics self-concept were more likely to use 'traditional' methods of instruction, such as lecturing and textbooks, and were more likely to blame a lack of time, interest, and motivation as reasons for not attempting new teaching strategies in Mathematics. Also, teachers with these low self-concepts specifically stated in interviews that female students are better at Reading and male students more adept at Mathematics and Science (Gunderson et al., 2011). Teachers' beliefs about ability and achievement can also be communicated through feedback and emotional responses such as pity and blame, but teachers are often unaware that they are communicating these beliefs through subtle cues (Upadaya & Eccles, 2014). If a teacher shows pity for a student who is failing, for example, this emotional response may signal to the student that he or she is worthy of that pity because of a lack of ability to succeed, which may—in the student's mind—support the idea that he or she is not capable of success in that content area (Upadaya & Eccles, 2014).

It certainly seems impossible to counterbalance the negative effects that female teachers can sometimes have on their female students. In fact, when presented with evidence that they conformed to a gender bias in the classroom, teachers changed behaviors to compensate for this fact and reduce the bias. Unfortunately, within a year, the teachers had reverted back to their original bias (Espinoza, da Luz Fontes, & Arms-Chavez, 2014).

By the time students get to the third grade, male students rate their own competence in Mathematics higher than female students rate themselves, even though there is no evidence of any difference in Mathematical performance (Chang, 2013). Even at this young age, if female students have already lowered their own expectations of success in Mathematics and other areas related to Science, Technology, Engineering, and Mathematics (STEM), it is not surprising that by the time female students reach middle school, they have set their sights upon paths and goals where they do feel more confident.

Developmental Theories

Since research has shown that female students are actually just as capable of achievement in Mathematics as males, the disparity in the participation of Science, Technology, Engineering, and Mathematics (STEM) careers by females could also be rooted in female students' self-concept. McLeod (2008) defined self-concept as the way that individuals think about, evaluate, or perceive themselves. More specifically, Lewis (1990) classified the development of self-concept into two parts: the existential self and the categorical self (as cited in McLeod, 2008). The existential self refers to the self-awareness a child gains at approximately two to three months old. This particular self involves the child's understanding that he or she is a separate entity from the world and from others, and that the child can interact with the world, rather than just existing in it (McLeod, 2008). The categorical self, however, is the part that may be more pertinent to the development of female attitudes and perceptions about achievement and abilities in Mathematics. As a child becomes able to perceive the categorical self, she begins to seek out definitions for who she is—categories to put herself into. McLeod (2008) clarified that the first two categories a child typically applies in this stage are age and gender, and that early in development, children perceive themselves in very concrete ways, such as hair color, height, and favorite things. Later on, however, children are able to include references regarding internal traits, comparisons to others, and the perceptions of others. Female students seeking clearly defined labels to attach to themselves may be particularly vulnerable to early classifications regarding Mathematics abilities, which could make it difficult for females to re-categorize themselves in the future.

Another notable theory that may be related to female students' achievement in Mathematics is Albert Bandura's Social Learning Theory. This theory suggests that children observe the behaviors of those around them and then afterwards, imitate some of the behaviors they have witnessed (McLeod, 2011). In Bandura's theory, those that are observed are referred to as models, which can include parents, friends, teachers, and even television characters. The way that these models behave provides examples for children to imitate (McLeod, 2011). Bandura observed that children appeared to be more likely to imitate models that are similar to themselves, and that it is therefore more likely that children replicate the behaviors of people of the same gender (McLeod, 2011). Since elementary school teachers tend to be primarily female, and teachers show more anxiety about Mathematics than any other major (Azar, 2010), it would be logical to make a connection between the anxieties that female teachers have about their Mathematics abilities to the anxieties that female students have about their own Mathematics abilities. Mothers are crucially important here, too, since daughters tend to identify strongly with their mothers. In fact, mothers are a bigger influence on a child's perceptions of their abilities than fathers, and since children look more closely at models of the same gender, daughters may be particularly influenced by their mothers' words, actions, and life choices (Leaper, Farkas, & Brown, 2012). If a mother chooses to stay at home and raise a family, for example, a daughter may internalize that behavior and model it later in life. Although a well-respected life choice, this behavior may be one factor that could preclude a female from pursuing a career in a Science, Technology, Engineering, and Mathematics (STEM) field. Likewise, if a mother expresses any anxious behaviors or negative talk regarding her abilities in Mathematics or Science—such as declaring that she is 'bad at math' or that frogs are 'dirty and gross'—daughters may reproduce that behavior in reference to their own abilities. This negative self-talk could further support the false assumption that females are poor performers in Mathematics and Science.

Possible Effects of STEM

There are so many factors that influence student achievement that it is incredibly difficult to make causal connections from any one factor (Mead, 2006), but strong positive messages about female Mathematics abilities—presented both at home and at school—are one way to begin to encourage females to pursue interests in Mathematics-related and Science-related fields. The incorporation of a Science, Technology, Engineering, and Mathematics (STEM) education in school districts across the country may be another very important step, particularly if Science, Technology, Engineering, and Mathematics (STEM) education can be shown to have an equal or greater affect on the academic achievement of female students versus male students.

Chapter III

METHODOLOGY

Introduction

The purpose of this field study was to investigate the possible effects of Science, Technology, Engineering, and Mathematics (STEM) education on the academic achievement of male and female students in grades three through eight in Mathematics. The independent variables for this study were the gender of participants and the years of assessment. The dependent variable was academic achievement in Mathematics as measured by the Tennessee Comprehensive Assessment Program (TCAP) test scores.

Research Questions

The following Research Questions are appropriate to this field study:

Research Question 1:

Does the integration of Science, Technology, Engineering, and Mathematics (STEM) education have an impact on the academic achievement of students in Mathematics in grades three through eight?

Research Question 2:

Does the integration of Science, Technology, Engineering, and Mathematics (STEM) education impact the academic achievement of males and females equally in Mathematics?

Null Hypotheses

The following Null Hypotheses are appropriate to this particular field study:

<u>Null Hypothesis 1</u>:

There will be no statistically significant difference in the academic success of students in Mathematics in grades three through eight before and after the implementation of Science, Technology, Engineering, and Mathematics (STEM).

<u>Null Hypothesis 2</u>:

There will be no statistically significant difference between the academic success of males versus females in Mathematics before and after the implementation of Science, Technology, Engineering, and Mathematics (STEM).

Research Design

This was a quantitative study. Only archival data were utilized to determine the impact that Science, Technology, Engineering, and Mathematics (STEM) education may have had on a student's academic achievement in Mathematics. A logistic regression analysis was used to determine if Science, Technology, Engineering, and Mathematics (STEM) implementation had an effect on the Mathematics achievement of male and female students as it pertained to the Tennessee Comprehensive Assessment Program (TCAP) scores.

Students were classified as either male or female, and the school year was categorized as either "no Science, Technology, Engineering, and Mathematics (STEM) implementation" or "Science, Technology, Engineering, and Mathematics (STEM) implementation". The year 2009 was designated as the year with no Science, Technology, Engineering, and Mathematics (STEM) implementation due to the fact that it was the last year in the Clarksville-Montgomery County School System (CMCSS) prior to any Science, Technology, Engineering, and Mathematics (STEM) integration in the district. The year 2013 was selected as the year to represent Science, Technology, Engineering, and Mathematics (STEM) implementation. After several years of gradually phasing in Science, Technology, Engineering, and Mathematics (STEM) across the district, 2013 was the first year that Science, Technology, Engineering, and Mathematics (STEM) was integrated into all schools across the entire district.

In the school year 2009-2010, the Clarksville-Montgomery County School System (CMCSS) began integrating Science, Technology, Engineering, and Mathematics (STEM) by introducing it into three pilot schools in the district: one elementary school, one middle school, and one high school. The following school year, 2010-2011, the district integrated Science, Technology, Engineering, and Mathematics (STEM) in all eighth and fifth grades across the district. In the school year 2011-2012, Science, Technology, Engineering, and Mathematics (STEM) was introduced in seventh and fourth grades across the district. The school year 2012-2013 was the final phase of Science, Technology, Engineering, and Mathematics (STEM) introduction That year, Science, Technology, Engineering, and Mathematics (STEM) was introduced in sixth grades and third grades across the district. By the end of the 2012-2013 school year, Science, Technology, Engineering, and Mathematics (STEM) had been integrated across the entire district in all grades three through eight (E. Bishop, personal communication, November 5, 2015).

The dependent variable was whether or not a student achieved proficiency in Mathematics on the Tennessee Comprehensive Assessment Program (TCAP). According to the Tennessee Department of Education (2015a), a designation of 'proficient' indicates that the student is able to "demonstrate mastery in academic performance, thinking abilities, and application of understandings that reflect the knowledge and skill specified by the grade/course level content standards and are prepared for the next level of study" (p. 5). In this field study, students were categorized as either "proficient" or "not proficient". With two independent variables and one dependent variable, all of which were categorical, the logistic regression model was appropriate.

Participants

The participants for this field study consisted of Clarksville-Montgomery County School System (CMCSS) students in grades three through eight in the years 2009 and 2013. In the year 2009, the sample consisted of 13,114 participants, while in the year 2013, the sample consisted of 12,730 participants.

Criterion Variable

In this field study, achievement was determined based on whether or not students demonstrated proficiency in Mathematics on the Tennessee Comprehensive Assessment Program (TCAP). Students exhibited proficiency in Mathematics by showing that they were able to "demonstrate mastery in academic performance, thinking abilities, and application of understandings that reflect the knowledge and skill specified by the grade/course level content standards and are prepared for the next level of study" (Tennessee Department of Education, 2015a, p. 5). The Tennessee Department of Education (TNDOE) classifies student achievement in several categories. Students who demonstrate proficiency are classified as "proficient", and students who are significantly above proficiency are classified as "advanced". Students who do not demonstrate proficiency are classified as "below proficient". Some school reports disaggregate student data ever further by classifying below-proficiency students as "far below proficiency" or "near proficiency" to indicate to educators which students may need the most intense interventions in order to achieve proficiency in a content area. For this field study, however, only classifications of "proficient" and "not proficient" were examined.

Predictor Variables

Although there are numerous factors that can impact the academic achievement of students, this field study focused on only two variables. The first variable was whether the student was a male or female, which was categorized as the student's gender. The second variable examined in this field study was whether or not the student demonstrated proficiency after receiving instruction in a year that integrated Science, Technology, Engineering, and Mathematics (STEM) education into the curriculum.

Gender. The participants in this field study were classified as either male or female based on their gender. This variable is categorical and mutually exclusive, since students can only be classified as either male or female, and not both.

Years of assessment. The school years examined in this field study were 2008-2009 and 2012-2013. Since the test scores are collected in the spring of each school year, the years of assessment were referred to as 2009 and 2013. The year 2009 was selected since it was the last year in the Clarksville-Montgomery County School System (CMCSS) before the integration of Science, Technology, Engineering, and Mathematics (STEM) integration in any school in the district. The year 2013 was selected because it was the first year that Science, Technology, Engineering, and Mathematics (STEM) was integrated into all schools across the entire district. Between 2009 and 2013, Science, Technology, Engineering, and Mathematics (STEM) was gradually phased into schools across the district. By the end of the 2012-2013 school year, Science, Technology, Engineering, and Mathematics (STEM) had been integrated across the entire district in grades three through eight (E. Bishop, personal communication, November 5, 2015).

Instrumentation

The instrument that was used in this study to collect student data was the Tennessee Comprehensive Assessment Program (TCAP), a criterion-referenced test that was administered in grades three through eight in the Clarksville-Montgomery County School System (CMCSS) under the guidance of the Tennessee Department of Education. The Tennessee Comprehensive Assessment Program (TCAP) was the state-wide assessment utilized to determine student academic proficiency in Mathematics, Science, Reading/Language Arts, and Social Studies in grades three through eight.

Data from the 2008-2009 school year were archived by the Tennessee Department of Education and available for the researcher to download on the Tennessee Department of Education website. Data from the 2012-2013 school year were not available on the Tennessee Department of Education website, but were provided to the researcher by the

Clarksville-Montgomery County School System (CMCSS) District Data Analyst. The data were disaggregated to reflect achievement levels (proficiency and non-proficiency) for males and females in grades three through eight for both 2009 and 2013. Only Mathematics data were examined. Using data provided, the researcher used the Statistical Package for the Social Sciences (SPSS) version 23 - software program to complete a binary logistic regression analysis in order to examine Mathematics achievement prior to and after the implementation of Science, Technology, Engineering, and Mathematics (STEM) education in the Clarksville-Montgomery County School System (CMCSS).

Assumptions

Although a binary logistic regression analysis does not require most of the same assumptions of linear regression, such as linearity, normality, or homogeneity of variance (Laerd Statistics, 2013), there are several assumptions that do need to be met. The first assumption is that the dependent variable is measured on a dichotomous scale. In the present analysis, the dependent variable was achievement, and participants were classified as either not proficient (coded as 0) or proficient (coded as 1). The first assumption was thus met.

The second assumption in logistic regression is the presence of one or more independent variables (Laerd Statistics, 2013). These variables must be either continuous or categorical. In this analysis, two independent variables were included: the participant's gender (male/female) and whether or not the participant received Science, Technology, Engineering, and Mathematics (STEM) instruction. Both independent variables were categorical, and therefore, the second assumption was met.

The next assumptions are independence of observations and the dependent variable having mutually exclusive categories (Laerd Statistics, 2013). These assumptions were met since the achievement of one participant did not affect, prevent, or influence the achievement of another student. Additionally, a participant could only be included in one of the two categories of the dependent variable; a student who was proficient could only be classified in the "proficient" category, and a student who was not proficient could only be classified in the "not proficient" category.

Finally, this type of analysis requires large sample sizes (Statistics Solutions, 2015). In this analysis, there were two samples taken. One sample was from 2009, the school year where no Science, Technology, Engineering, and Mathematics (STEM) was integrated into schools, and one sample from 2013, the school year with Science, Technology, Engineering, and Mathematics (STEM) integration. Hosmer and Lemeshow recommend sample sizes larger than 400, since smaller sample sizes produce a lower power (Bewick, Cheek, & Ball, 2005). In the 2009 sample, there were 13,114 participants, and in the 2013 sample, there were 12,730 participants. The amount of data collected and utilized in this field study easily satisfies the requirement of large sample sizes.

Procedure

The data utilized for this study were obtained from the State of Tennessee's Department of Education website and from the Clarksville-Montgomery County School

System (CMCSS) District Data Analyst. The data were all archived data, and were disaggregated to show the number of males and females who demonstrated proficiency in Mathematics during two different school years. One of the school years, 2008-2009, was before any Science, Technology, Engineering, and Mathematics (STEM) education had been implemented across the Clarksville-Montgomery County School System (CMCSS). The other school year, 2012-2013, was the first year of full implementation after Science, Technology, Engineering, and Mathematics (STEM) education had been gradually phased into schools across the district.

First, all subjects were categorized as in a year of either Science, Technology, Engineering, and Mathematics (STEM) implementation or no Science, Technology, Engineering, and Mathematics (STEM) implementation. Next, they were further categorized as male or female, and as either proficient in Mathematics or not proficient in Mathematics.

The researcher utilized the data to complete a binary logistic regression analysis. The results of the logistic regression are reported in Chapter IV of this field study and were provided to the Clarksville-Montgomery County School System (CMCSS) school district.

Data Analysis Plan

Archival data gathered from the Tennessee Department of Education website were entered into the Statistical Package for the Social Sciences (SPSS) software program. The Alpha level of statistical significance for this study was set at $p < 0.05$ to determine whether the null hypotheses would be retained or rejected. The researcher evaluated the data to determine whether or not there was a statistically significant difference between the achievement of male and female students in Mathematics before and after Science, Technology, Engineering, and Mathematics (STEM) implementation in the Clarksville-Montgomery County School System (CMCSS). Based upon the findings, the researcher either rejected or retained each null hypothesis.

Chapter IV
DATA ANALYSIS AND RESULTS

This research study examined the possible effects of integrating Science, Technology, Engineering, and Mathematics (STEM) upon student achievement. Students in the Clarksville-Montgomery County School System in Clarksville, Tennessee in grades three through eight in the years of 2009 and 2013 were participants in the study. An end-of-year state standardized test known as the Tennessee Comprehensive Assessment Program (TCAP) was used to measure achievement levels in Mathematics. Students were classified as either proficient or not proficient on the Tennessee Comprehensive Assessment Program (TCAP) assessment, which was labeled as "achievement", the dependent variable. The independent variables were the gender of the participants and whether or not Science, Technology, Engineering, and Mathematics (STEM) was incorporated in the curriculum that year. These variables were analyzed to determine whether either or both variables had any effect on Mathematics achievement. A binary logistic regression analysis was completed on the data and it was determined that incorporating a Science, Technology, Engineering, and Mathematics (STEM) education into the curriculum had a significant impact upon whether or not a student achieved proficiency on the Mathematics portion of the Tennessee Comprehensive Assessment Program (TCAP).

The data examined implied that, of the data used ($N = 25,844$), students who did not participate in the Science, Technology, Engineering, and Mathematics (STEM) program were 13.037 times more likely to achieve proficiency on the Mathematics

Tennessee Comprehensive Assessment Program (TCAP) than those students who did participate in the Science, Technology, Engineering, and Mathematics (STEM) program. Additionally, the data also imply that overall, female students were 1.183 times more likely to achieve proficiency on the Mathematics Tennessee Comprehensive Assessment Program (TCAP) than male students.

In 2009, the year with no Science, Technology, Engineering, and Mathematics (STEM) integration, females demonstrated proficiency 94.8% of the time compared to male students demonstrating proficiency 91.7% of the time in the same year. In 2013, the year with Science, Technology, Engineering, and Mathematics (STEM) integration, however, female students demonstrated proficiency in Mathematics 52.4% of the time compared to male students demonstrating proficiency 50.4% of the time in the same year.

Research Questions

The following Research Questions are appropriate to this field study:

<u>Research Question 1</u>:

Does the integration of Science, Technology, Engineering, and Mathematics (STEM) education have an impact on the academic achievement of students in Mathematics in grades three through eight?

<u>Research Question 2</u>:

Does the integration of Science, Technology, Engineering, and Mathematics (STEM) education impact the academic achievement of males and females equally in Mathematics?

Null Hypotheses

The following Null Hypotheses are appropriate to this particular field study:

Null Hypothesis 1:

There will be no statistically significant difference in the academic success of students in Mathematics in grades three through eight before and after the implementation of the Science, Technology, Engineering, and Mathematics (STEM).

Null Hypothesis 2:

There will be no statistically significant difference between the academic success of males versus females in Mathematics before and after the implementation of Science, Technology, Engineering, and Mathematics (STEM).

Data Collection and Recording

The data collected for this field study were based solely on archival data from the 2008-2009 and 2012-2013 school years. Data from 2008-2009 were collected from the Tennessee Department of Education (TNDOE) website under the student achievement reports for the Clarksville-Montgomery County School System (CMCSS) district. Data from 2012-2013 were unavailable from the Tennessee Department of Education (TNDOE) website and were provided to the researcher by the Clarksville-Montgomery County School System (CMCSS) District Data Analyst.

Descriptive Statistics

The participants in this study consisted of 25,844 male and female students in grades three through eight who participated in the Mathematics assessment on the

Tennessee Comprehensive Assessment Program (TCAP) in the Clarksville-Montgomery County School System (CMCSS) in the state of Tennessee. Of those students, 13,114 were included in the first sample, referred to as the year with no Science, Technology, Engineering, and Mathematics (STEM) integration, which was the year 2009. In 2009, the male students comprised 50.9 percent of the sample, while females represented the remaining 49.1 percent. In the state of Tennessee at the time, males represented 48.7 percent of the population, with females as 51.3 percent of the population (United States Census Bureau, 2009). Refer to Table 1 for demographic data for the year 2009. The 2009 sample in this field study does characterize a sample that is representative of the population at the time.

Table 1

Demographic Profile of the Sample v. the State of Tennessee Population for 2009

Demographic	Sample Frequency	Sample Percentage	State of Tennessee Frequency	State of Tennessee Percentage
Gender				
Male	6669	50.9	3069243	48.7
Female	6445	49.1	3227011	51.3

The second sample in this field study can be referred to as the year with Science, Technology, Engineering, and Mathematics (STEM) integration, and was the year 2013. The sample size in that year was 12,730 students, where male students comprised 50.3 percent of the sample, and females represented the remaining 49.7 percent. In the state of Tennessee at the time, males represented 48.8 percent of the population, with females as

51.2 percent of the population (United States Census Bureau, 2013). Refer to Table 2 for demographic data for the year 2013. The 2013 sample in this field study does characterize a sample that is representative of the population at the time.

Table 2

Demographic Profile of the Sample v. the State of Tennessee Population for 2013

Demographic	Sample Frequency	Sample Percentage	State of Tennessee Frequency	State of Tennessee Percentage
Gender				
Male	6403	50.3	3167094	48.8
Female	6327	49.7	3328884	51.2

Achievement data for the state of Tennessee were also available for 2009 and 2013. In the year 2009, 93.2 percent of students in the sample were proficient on the Mathematics portion of the Tennessee Comprehensive Assessment Program (TCAP), while 90.6 percent of the population was proficient in the same assessment during that same year. The data imply that the 2009 year-group sample is representative of the population in the state of Tennessee at the time. In the year 2013, 51.4 percent of students in the sample were proficient on the Mathematics portion of the Tennessee Comprehensive Assessment Program (TCAP), while 50.8 percent of the population was proficient in the same assessment during that same year (Tennessee Department of Education, 2016a). The data imply that the 2013 year-group sample is representative of the population in the state of Tennessee at the time. Refer to Table 3 for this achievement data.

Table 3

Achievement of the Sample v. the State of Tennessee Population

Year	Sample Frequency	Sample Percentage	State of Tennessee Frequency	State of Tennessee Percentage
Proficiency				
2009	12225	93.2	396612	90.6
2013	6547	51.4	*	50.8

Note: * = Frequency of proficiency for the state of Tennessee was unavailable for the year 2013, although the percentage was accurately reported as listed.

In this field study, 13,114 students participated in the 2009 sample with no Science, Technology, Engineering, and Mathematics (STEM) integration. Of those participants, 93.2% scored proficient or above on the Mathematics portion of the Tennessee Comprehensive Assessment Program (TCAP). The other 6.8% of participants did not achieve proficiency on the Mathematics Tennessee Comprehensive Assessment Program (TCAP) (see Figure 1). Of the 12,730 students who participated in the sample with Science, Technology, Engineering, and Mathematics (STEM) integration, 51.4% scored proficient on the Mathematics Tennessee Comprehensive Assessment Program (TCAP). The remaining students, 48.6% of participants, did not achieve proficiency on the Mathematics Tennessee Comprehensive Assessment Program (TCAP) after Science, Technology, Engineering, and Mathematics (STEM) integration (see Figure 2).

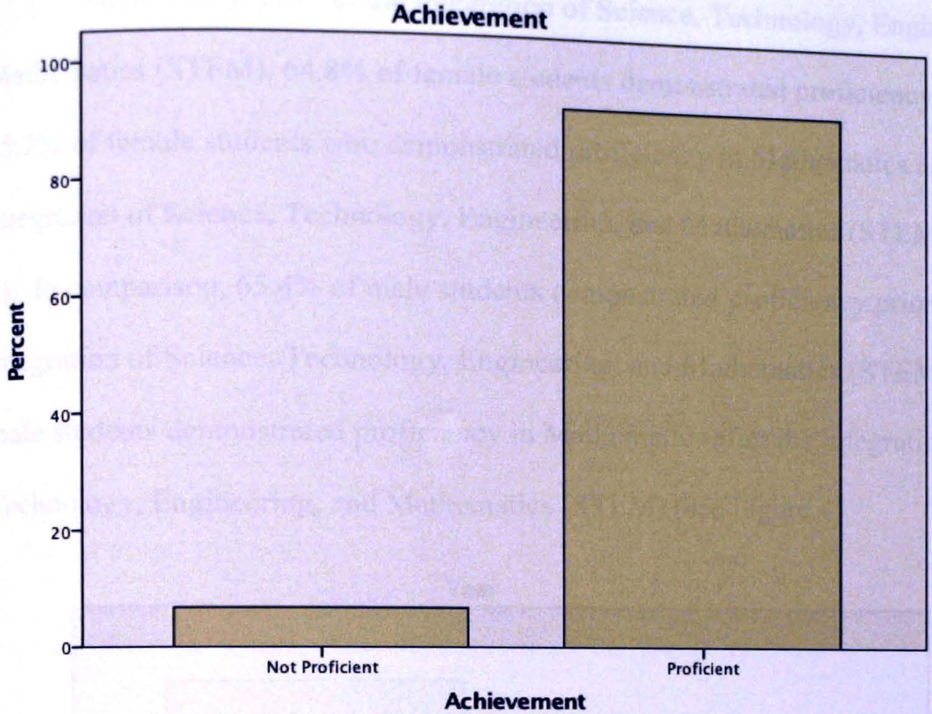

Figure 1. Student Proficiency before STEM Integration

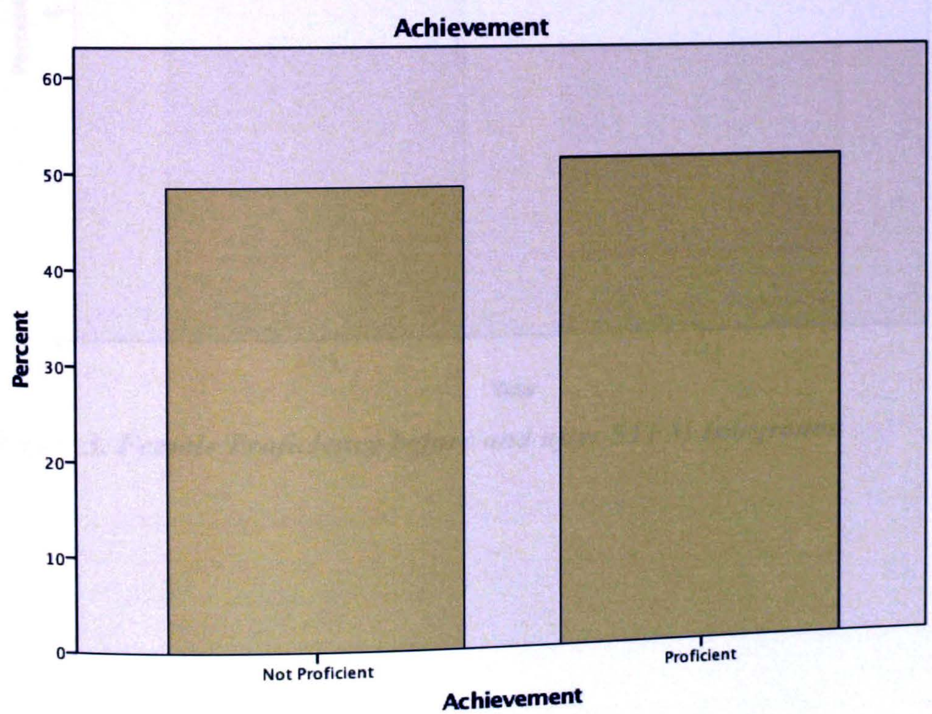

Figure 2. Student Proficiency after STEM Integration

Additionally, prior to the integration of Science, Technology, Engineering, and Mathematics (STEM), 64.8% of female students demonstrated proficiency, compared to 35.2% of female students who demonstrated proficiency in Mathematics after the integration of Science, Technology, Engineering, and Mathematics (STEM) (see Figure 3). In comparison, 65.4% of male students demonstrated proficiency prior to the integration of Science, Technology, Engineering, and Mathematics (STEM) and 34.6% of male students demonstrated proficiency in Mathematics after the integration of Science, Technology, Engineering, and Mathematics (STEM) (see Figure 4).

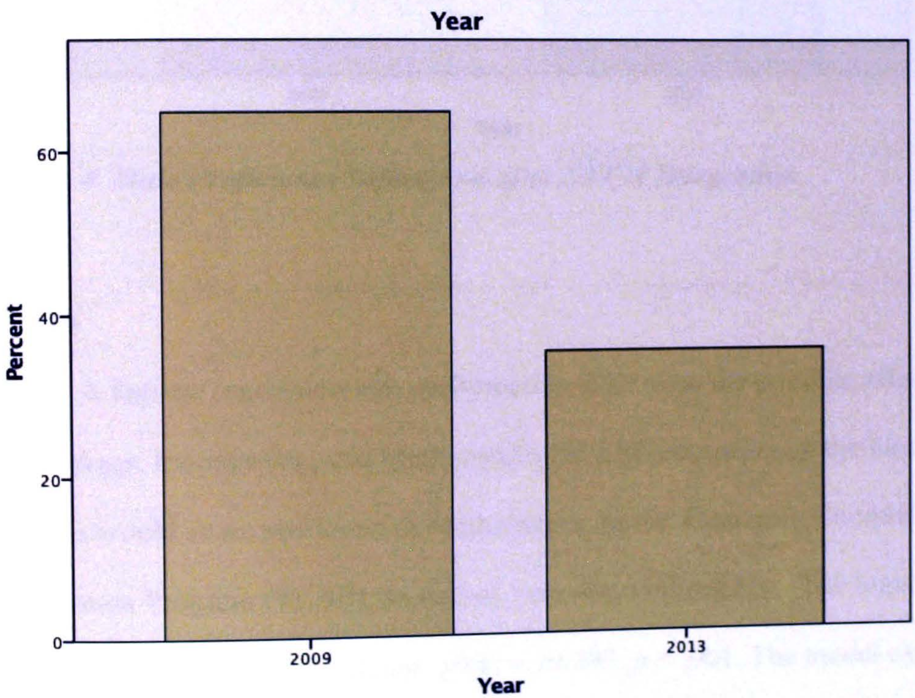

Figure 3. Female Proficiency before and after STEM Integration

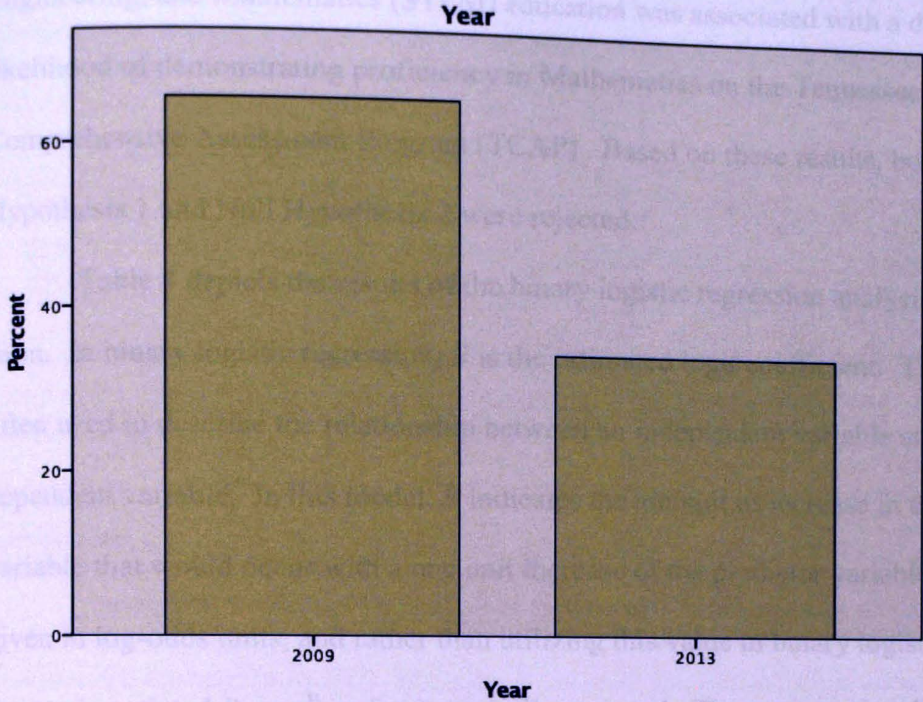

Figure 4. Male Proficiency before and after STEM Integration

Results

A logistic regression was performed to determine the possible effects of Science, Technology, Engineering, and Mathematics (STEM) education on the likelihood that students would score proficient in Mathematics on the Tennessee Comprehensive Assessment Program (TCAP), an end-of-year standardized test. The logistic regression model was statistically significant, $\chi^2(4) = 29.397, p < .001$. The model explained 31.0% (Nagelkerke R^2) of the variance in achievement and correctly classified 72.4% of cases. The data suggest that females were 1.183 times more likely to exhibit Mathematics proficiency than males. Additionally, the data indicate that students who did not receive Science, Technology, Engineering, and Mathematics (STEM) education were 13.037 times more likely to be proficient in Mathematics. Receiving Science, Technology, Engineering, and Mathematics (STEM) education was associated with a decreased likelihood of demonstrating proficiency in Mathematics on the Tennessee Comprehensive Assessment Program (TCAP). Based on these results, both Null Hypothesis 1 and Null Hypothesis 2 were rejected.

Table 4 depicts the results of the binary logistic regression analysis in tabular form. In binary logistic regression, *B* is the estimated logit coefficient. This value is often used to describe the relationship between an independent variable and the dependent variable. In this model, *B* indicates the amount of increase in the dependent variable that would occur with a one unit increase of the predictor variable. *B* values are given in log-odds units, and rather than utilizing this value in binary logistic regression, the exponentiated *B*, or e^B, value is typically reported. The exponentiated *B*, or e^B, is the odds ratio for the model. It describes the odds of the dependent variable occurring with respect to the independent variables (Institute for Research and Digital Education, 2016). In Table 4, the e^B for gender is 1.183. Since the reference category for this variable is males, the odds ratio e^B suggests that females are 1.183 times more likely than males to be proficient on the Mathematics portion of the Tennessee Comprehensive Assessment Program (TCAP). For the Science, Technology, Engineering, and Mathematics (STEM) variable, the reference category is after Science, Technology, Engineering, and Mathematics (STEM) integration. For this variable, the model suggests that students who did not receive Science, Technology, Engineering, and Mathematics (STEM) education are 13.037 times more likely to demonstrate proficiency than students who did receive Science, Technology, Engineering, and Mathematics (STEM) education. The column titled *S.E.* indicates the standard error of the variable.

Table 4
Summary of Binary Logistic Regression Analysis for Variables Predicting Mathematics Achievement on the Tennessee Comprehensive Assessment Program (TCAP)

Predictor	*B*	*S.E.*	e^B
Gender	0.168*	0.032	1.183
STEM	2.568*	0.039	13.037
Constant	-0.026	0.024	0.974

Note: Gender coded as 1 for *male* and 0 for *female*. STEM coded as 1 for *after STEM integration* and 0 for *before STEM integration.* Males and after STEM integration are the reference categories. e^B = exponentiated *B*. $*p < .001$.

Effect Size

According to Bewick, Cheek, and Ball (2005), there are two R^2 statistics reported in a logistic regression model. The Cox & Snell R^2 has a maximum value of less than one, and is not typically reported, since it can be difficult to relate this R^2 value to the R^2 value typically utilized in linear models. For this reason, an adjusted version of the Cox & Snell R^2, known as the Nagelkerke R^2, is typically reported in logistic regression analysis. The Nagelkerke R^2 ranges from zero to one, and more closely resembles the R^2 values of a typical linear regression model, which is why it is much more preferred. The Nagelkerke R^2 does not indicate the goodness of fit of the model, but rather, how useful the independent variables are at predicting the dependent variable. The R^2 value is the proportion of the total variance in the criterion variable—in this field study, achievement—that can be explained by the predictor variables, gender and Science, Technology, Engineering, and Mathematics (STEM) integration. The remaining variance in the model is unexplained, and considered "error" variance, since it cannot be attributed to predictor variables not examined in this model. The R^2 value can be referred to as "a measure of effect size" (Bewick, Cheek, & Ball, 2005, p. 115). In the current logistic regression model, the Nagelkerke R^2 was 0.310, which indicates that the model explained 31% of the variance in achievement.

Discussion of Hypotheses

Based on the results of the binary logistic regression, it is possible to answer both research questions with confidence.

Null Hypothesis 1. The first hypothesis was that there would be no statistically significant difference in the academic success of students in Mathematics in grades three through eight before and after the implementation of Science, Technology, Engineering, and Mathematics (STEM). The analysis determined that there is a statistically significant difference in the academic achievement of students in grades three through eight after the implementation of Science, Technology, Engineering, and Mathematics (STEM). Therefore, the first null hypothesis is rejected.

Null Hypothesis 2. The second hypothesis was that there would be no statistically significant difference between the academic success of males versus females in Mathematics before and after the implementation of Science, Technology, Engineering, and Mathematics (STEM). The analysis determined that there is a statistically significant difference between the academic achievement of males and females before and after the implementation of Science, Technology, Engineering, and Mathematics (STEM). Therefore, the second null hypothesis is also rejected.

CHAPTER V

DISCUSSION

Summary of Study

The purpose of this field study was to explore the possible effects of Science, Technology, Engineering, and Mathematics (STEM) on the Mathematics achievement of male and female students in the Clarksville-Montgomery County School System (CMCSS). This study utilized archival data from the years 2009 and 2013, and examined the Mathematics achievement of 25,844 students in grades three through eight in the Clarksville-Montgomery County School System (CMCSS). The researcher conducted a binary logistic regression analysis to determine the statistical significance of the Science, Technology, Engineering, and Mathematics (STEM) model of instruction on the Mathematics achievement of male and female students in grades three through eight.

This field study found that, overall, there was a statistically significant difference between the Mathematics achievement of students before and after the integration of Science, Technology, Engineering, and Mathematics (STEM) education in the schools examined. This field study also found that there was a statistically significant difference between the Mathematics achievement of male students versus female students after the integration of Science, Technology, Engineering, and Mathematics (STEM) education in schools.

Limitations

Although there are many limitations to any research, there were three main limitations relevant to this field study. The first limitation in this study was that academic achievement was determined based on a single assessment. The Tennessee Comprehensive Assessment Program (TCAP) was the only measure of achievement used in this study to determine whether or not a student was academically successful in Mathematics. Although there were other measures of student performance available, such as student growth scores provided by the Tennessee Value-Added Assessment System (TVAAS), the researcher only examined the achievement of students on the Tennessee Comprehensive Assessment Program (TCAP). In this field study, the research questions dealt solely with the possibility that the Clarksville-Montgomery County School System's (CMCSS) Science, Technology, Engineering, and Mathematics (STEM) initiative might have some affect on the achievement of students. Since achievement—not growth—was the measure being examined, it was appropriate to only examine the performance data from Tennessee Comprehensive Assessment Program (TCAP) reports. It is important to remember, however, that the Tennessee Comprehensive Assessment Program (TCAP) represents a single snapshot of a student's performance on a single day out of an entire school year, and therefore may not represent an altogether accurate picture of a student's performance level. Another option for this field study would have been to examine the performance of students on class assignments, unit assessments, and benchmark tests. Incorporating this many assessments might lead to a more accurate picture of student achievement in Mathematics, but since class assignments and unit tests could vary in difficulty from school to school or even teacher to teacher, it would have been incredibly challenging to determine how one student's achievement level related to another's, even if this kind of data were available to the researcher. Ideally, every student performed to his or her own highest level possible on the Mathematics portion of the

Tennessee Comprehensive Assessment Program (TCAP) assessment, but relying so heavily on a single assessment was clearly a limitation of this study.

A second limitation in this study was that the Tennessee Comprehensive Assessment Program (TCAP) did not account for all variables that may affect student achievement. This field student examined only two variables that affect student achievement: gender and whether or not the student had participated in Science, Technology, Engineering, and Mathematics (STEM). Although the model suggests that these two variables alone accounted for nearly one-third of the variance in student achievement in Mathematics (Nagelkerke $R^2 = 0.310$), it did not account, for example, for variables such as student anxiety, teacher effectiveness, socioeconomic status, race, disability, or student interests and motivation.

A third limitation of this research was that the study included the scores of every test taker in the district. There was no way to know which of the nearly 26,000 students examined in this study received a full year of Science, Technology, Engineering, and Mathematics (STEM) instruction, and which others may have only recently enrolled in the district. One of the research questions examined was whether or not the introduction of the Science, Technology, Engineering, and Mathematics (STEM) curriculum had an impact on student achievement in Mathematics. Students in the year 2009, defined as the year with no Science, Technology, Engineering, and Mathematics (STEM) integration, *should not have* received any Science, Technology, Engineering, and Mathematics (STEM) instruction in that year. For test takers who spent the entire year in the Clarksville-Montgomery County School System, this presumption was correct, since Science, Technology, Engineering, and Mathematics (STEM) was not introduced in any school in the district until the following school year, 2009-2010. If, however, a student in the 2009 sample had transferred into the district from a school system outside of the Clarksville-Montgomery County School System (CMCSS) or from another state that had already implemented Science, Technology, Engineering, and Mathematics (STEM), that particular student's achievement score may have skewed the 2009 school year results. The opposite situation in the year 2013, defined as the year with Science, Technology, Engineering, and Mathematics (STEM) integration, could have also occurred. If a student in the 2013 sample had transferred into the district from a school system that had not been incorporating Science, Technology, Engineering, and Mathematics (STEM), that particular student's achievement score may have skewed the 2013 school year results.

The fourth limitation of this study was that the data collected for the non-Science, Technology, Engineering, and Mathematics (STEM) year sample (N = 13,114) and the data collected for the Science, Technology, Engineering, and Mathematics (STEM) year sample (N = 12,730) were only collected from one-year periods. The year 2009 was selected to represent the year with no Science, Technology, Engineering, and Mathematics (STEM) integration, and the year 2013 was selected to represent the year with Science, Technology, Engineering, and Mathematics (STEM) integration. More reliable results may be possible by utilizing data for each sample that span several years. Instead of selecting only 2009 for the sample that did not include Science, Technology, Engineering, and Mathematics (STEM), for example, a wider range of years may be selected to reflect Mathematics achievement of students prior to the integration of Science, Technology, Engineering, and Mathematics (STEM).

Assumptions

One assumption in this field study was that all students performed to the best of their abilities on the Tennessee Comprehensive Assessment Program (TCAP) test in the area of Mathematics during the years 2009 and 2013. As discussed earlier, there are many factors that can affect student achievement. Since the Tennessee Comprehensive Assessment Program (TCAP) in Mathematics represents a single picture of achievement for a student, every student in the sample (N = 25,844) was assumed to have performed to the ultimate peak of their possible achievement level. Although teachers, parents, administrators, and district personnel may do everything possible to ensure that student performance is maximized on the day of the assessment, in the end, it is really up to the individual student's intrinsic motivation to perform.

A second assumption in this study was that a student's Mathematics performance on the Tennessee Comprehensive Assessment Program (TCAP) test was a result of the Science, Technology, Engineering, and Mathematics (STEM) initiative implemented by the Clarksville-Montgomery County School System (CMCSS) school district. The data suggest a very strong negative relationship between Mathematics achievement and the integration of the Science, Technology, Engineering, and Mathematics (STEM) curriculum, but it does not account for all the variance in this model.

A third assumption of this field study was that the treatment of all students was equal in classrooms across the Clarksville-Montgomery County School System (CMCSS) school district. Student treatment is one of a plethora of factors affecting achievement, and it could have been especially important if teachers exhibited strong bias toward one group of students. Also, as discussed in Chapter 3, there is significant evidence that indicates that not only are elementary age children highly influenced by the adults in their lives, but that they are even more strongly influenced by adults of the same gender (The University of Chicago, 2010). If so, teachers with anxieties in Mathematics could have affected the performance of students of the same gender in their classrooms. In much the same way, however, teachers who expressed confidence in their Mathematics abilities could have also affected the performance of same-gender students. Either way, student treatment represents another variable to consider that may have affected the data examined.

Finally, this field study assumes that all teachers in the Clarksville-Montgomery County School System (CMCSS) were exposed to the same Science, Technology, Engineering, and Mathematics (STEM) training and implemented Science, Technology, Engineering, and Mathematics (STEM) in the same way in all classrooms. Although some educators in the district may have been supportive of the Science, Technology, Engineering, and Mathematics (STEM) curriculum model right away, others may have taken more time to become accustomed to the change in methodology, while still others may have resisted the shift towards Science, Technology, Engineering, and Mathematics (STEM) altogether. With at least three possible scenarios to consider when determining whether or not teachers even supported the integration of Science, Technology, Engineering, and Mathematics (STEM), it is questionable whether instruction was delivered with equal enthusiasm in every classroom in the Clarksville-Montgomery County School System (CMCSS). In addition to personal attitudes towards Science, Technology, Engineering, and Mathematics (STEM), teachers should have all received the same rigorous training on the Science, Technology, Engineering, and Mathematics

(STEM) curriculum model, including strategies for how to implement it successfully in the classroom. However, the problem with this assumption is that it does not account for teachers who miss a day of training, take a leave of absence, enter the school system partially through the year, or have prior experience with implementing Science, Technology, Engineering, and Mathematics (STEM) in the classroom.

Recommendations

Based on the findings of this field study, the following recommendations are made:

1. The Clarksville-Montgomery County School System (CMCSS) should discontinue the Science, Technology, Engineering, and Mathematics (STEM) program in its current form.
2. The Clarksville-Montgomery County School System (CMCSS) should discontinue the use of the Tennessee Comprehensive Assessment Program (TCAP) as a measure of student achievement.
3. The Clarksville-Montgomery County School System (CMCSS) should examine the methods utilized to train Science, Technology, Engineering, and Mathematics (STEM) teachers, and determine how to maximize student achievement using the Science, Technology, Engineering, and Mathematics (STEM) model of education.

Discussion of Recommendations

It would be beneficial to the achievement of male and female students for the Clarksville-Montgomery County School System (CMCSS) to discontinue the Science, Technology, Engineering, and Mathematics (STEM) program in its elementary and middle schools. Although the Clarksville-Montgomery County School System (CMCSS) may have spent a significant amount of funding to implement Science, Technology, Engineering, and Mathematics (STEM) across the district, the data suggest that the program is not working. The data show a very strong negative correlation between Mathematics achievement and the Science, Technology, Engineering, and Mathematics (STEM) program. More specifically, students in grades three through eight who did not receive Science, Technology, Engineering, and Mathematics (STEM) education were more than 13 times more likely to be proficient in Mathematics than students who did receive Science, Technology, Engineering, and Mathematics (STEM) instruction. With such strong evidence against the current Science, Technology, Engineering, and Mathematics (STEM) program in the school district, the Clarksville-Montgomery County School System (CMCSS) should consider whether or not the Science, Technology, Engineering, and Mathematics (STEM) program as it is currently being implemented will truly help prepare students for college and careers.

If the Clarksville-Montgomery County School System (CMCSS) is unwilling or unable to discontinue the Science, Technology, Engineering, and Mathematics (STEM) program in its elementary and middle schools, it would be advantageous to discontinue its assessment of student proficiency using the Tennessee Comprehensive Assessment Program (TCAP) in favor of an assessment that more closely aligns with the instructional model utilized with Science, Technology, Engineering, and Mathematics (STEM) education. Unfortunately, the Clarksville-Montgomery County School System (CMCSS) is required by the state of Tennessee to assess students with a specific end-of-year standardized test, such as the Tennessee Comprehensive Assessment Program (TCAP). Abandoning this specific assessment, then, seems an unlikely event, although this action should be seriously considered if the opportunity becomes available to measure achievement using a standardized test that aligns with the Science, Technology, Engineering, and Mathematics (STEM) curriculum model.

The final recommendation is preferable if the Clarksville-Montgomery County School System (CMCSS) intends to continue using the Science, Technology, Engineering, and Mathematics (STEM) model of education in grades three through eight, and continues utilizing the results of the Tennessee Comprehensive Assessment Program (TCAP) or some other equivalent assessment to determine proficiency. In this situation, the Clarksville-Montgomery County School System (CMCSS) should refine the existing teacher education program that supports Science, Technology, Engineering, and Mathematics (STEM) educators in the district to ensure that all teachers, to the greatest extent possible, are delivering Science, Technology, Engineering, and Mathematics (STEM) instruction with the same high level of rigor, dedication to the curriculum model, and proficiency of instruction.

Conclusions

Many who hope to have a significant impact on the success of students in life after schooling have favored the implementation of Science, Technology, Engineering, and Mathematics (STEM) education. Unfortunately, student success or failure on a standardized test does not always correlate to the same outcome in the real world. A goal of schools, then, is to determine ways to ensure that students are ready for either college or a career after graduation. The Science, Technology, Engineering, and Mathematics (STEM) program currently utilized in the Clarksville-Montgomery County School System (CMCSS) is a curriculum model that was designed to ensure this readiness. Unfortunately, the data examined in this field study indicate that Science, Technology, Engineering, and Mathematics (STEM) had a significantly negative effect on student achievement in Mathematics. This negative effect may be due to the fact that the Science, Technology, Engineering, and Mathematics (STEM) curriculum model utilizes a vastly different model of instruction than what is assessed on the Tennessee Comprehensive Assessment Program (TCAP), the end-of-year standardized test required by the state of Tennessee. Additionally, although current research indicates that in elementary and middle school, males and females tend to be equally successful in Mathematics and Science, the data examined in this field study imply that females in grades three through eight in the Clarksville-Montgomery County School System (CMCSS) are actually *more* likely to display proficiency in Mathematics than their male counterparts. The Science, Technology, Engineering, and Mathematics (STEM) program in its current form appears to benefit female students slightly more than males. However, the overall Mathematics achievement of students in grades three through eight is negatively affected so strongly by the integration of Science, Technology, Engineering, and Mathematics (STEM) in this district that the instructional model must be reconsidered, or some other steps must be taken to ensure student success.

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APPENDICES

APPENDIX A

Approval Letter from the Clarksville-Montgomery County School System (CMCSS)

Granting Permission to Conduct the Study

CLARKSVILLE
MONTGOMERY COUNTY
SCHOOL SYSTEM

From: Dr. Kimi Sucharski
CMCSS Accountability
612 Gracey Ave
Clarksville, TN 37040

July 15, 2015

To: Amy O'Neill

Subject: Request to Conduct Research in CMCSS

The Clarksville Montgomery County School System Research Committee has met and approved your request to conduct research in the District examining the influence of STEM implementation on the math and science achievement of males and females in grades 3 – 8 utilizing archival data.

Sincerely,

Dr. Kimi Sucharski
CMCSS Accountability and Assessment
Kimi.sucharski@cmcss.net
(931) 920-7813 office

APPENDIX B

Approval Letter from the Austin Peay State University (APSU) Institutional Review Board (IRB) Granting Permission to Conduct the Study

AUSTIN PEAY STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD

Date: 11/23/2015

RE 15-057: The Effects of STEM on the Academic Achievement of Males and Females in Math and Science in Grades Three through Eight

Dear Amy O'Neill,

We appreciate your cooperation with the human research review process. This letter is to inform you that study 15-057 has been reviewed on expedited level. It is my pleasure to inform you that your study has been approved, and meets the criteria for exempt from further review. Exemption is granted on the basis of 45 CFR 46.101(b)(4): research involves only the collection and study of existing data that will be provided to the PI as de-identified aggregated data. You are free to conduct the study at this time.

This approval is subject to APSU Policies and Procedures governing human subject research. The IRB reserves the right to withdraw approval if unresolved issues are raised during the review period. Any changes or deviations from the approved protocol must be submitted in writing to the IRB for further review and approval before continuing. This approval is for one calendar year. The expiration date is 11/23/2016. If you have any questions or require further information, you can contact me by phone (931-221-6106) or email (shepherdo@apsu.edu).

Sincerely,

Omie Shepherd

Omie Shepherd, Ph. D. Chair, APIRB

Cc: Dr. Gary Stewart