CULTIVATING THE ROOTS OF STEM:

INVESTIGATING THE INFLUENCE OF A STEM PROGRAM ON TEACHERS' EFFICACY AND ADOLESCENTS' ATTITUDES TOWARD STEM

by

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A DISSERTATION

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ABSTRACT

The newest science standards and national economy demand a committed emphasis to STEM integration in K-12 education. The need for STEM programs in K-12 education continues to grow, specifically in the formative adolescent years. In response, one public school district pursued and was awarded a grant to implement a STEM program. This research study is an investigation into the impact of this program on both students and teachers throughout the school district.

The purpose of this mixed method, three-article dissertation was to probe the effectiveness of the district-wide STEM program on adolescents and their teachers. The researcher was particularly attentive to the relationship between teacher efficacy in STEM and students' confidence in and attitudes toward STEM, whether a difference existed in groups of teachers and students who were surveyed before and after the STEM program was implemented, and whether a difference existed in terms of race and gender regarding students' levels of STEM confidence. Historical data including both teacher and student responses that were collected by the district were used for a variety of analyses. The studies found that there was no relationship between teachers' STEM efficacy and students' STEM confidence, but there was an increase in both groups' levels of STEM efficacy and confidence after the program. Analysis of teachers' comments indicated that three areas of priority concentration for STEM professional development are time, efficacy, and equipment. The studies also found that there were no differences regarding gender or race in terms of STEM confidence among students. Females' STEM confidence increased after the STEM program, while minority students' STEM confidence did not. The studies provide both quantitative and qualitative analyses to the national focus on STEM education and best practices for equipping teachers and their students to have positive experiences with STEM learning.

DEDICATION

This dissertation is dedicated to my Captain, Sassafras, Sweet Love, and Pearl. Your unwavering faith in me and your encouragement have been the wind in my sails. God purposed me for the work, but you anchor me to this topic. I love you all to the moon.

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CHAPTER I

INTRODUCTION

Likened to the *Sputnik* crisis of the 1960s, the current cause for alarm in the United States education community is the disconcerting lack of contributors to the areas on which our nation's future is reliant: science, technology, engineering, and math (STEM) (Brown, Concannon, Marx, Donaldson, & Black, 2016). There is a significant shortage of workers for the STEM fields on which many modern and future work depends (Rice, Barth, Guadagno, Smith, & McCallum, 2013). As a result of this national crisis, the Next Generation Science Standards were created as a bipartisan partnership between public and private entities, including Intel, Microsoft, the Bill and Melinda Gates Foundation, Chevron, AT&T, Boeing, IBM, and more (Achieve, 2013; Hoeg & Bencze, 2017a, 2017b). K-12 education and business leaders are uniquely aligned in the effort to increase the number of students interested in STEM with the hope of directing more eventual professionals in those fields (Hoeg & Bencze, 2017a; Miller, 2018; Osei-Kofi & Torres, 2015). Additionally, there remains a significant underrepresentation of minorities and females in the fields of science, technology, engineering, and math (Fouad & Santana, 2017). Unlike other initiatives in K-12 education, business leaders are specifically eager to support STEM because of their shared interest in the effective teaching of these subjects (Rosen, 2012).

For the purposes of this study, STEM education is defined as authentic, problem-based learning that crosses science with two or more other categories of technology, engineering, and math (Hoeg & Bencze, 2017b; Kelley, 2012). Although STEM initiatives are growing in popularity in modern education due to an influx of grants from the business community, many instructional leaders lack understanding in the targeted focus of the STEM concept. A review of the literature in this field indicates a clear definition of STEM education as an instructional approach that eliminates the fences traditionally established around the four areas of science, technology, engineering, and math and integrates them into authentic and challenging learning experiences (Comer, Sneider, & Vasquez, 2013). Russell, Meredith, Childs, Stein, and Prine (2015) indicated that implementation of STEM education varies significantly. There is a lack of consistency in framework and methodologies for instructional leaders and researchers who are working to implement STEM education (Mitts, 2016; Russell et al., 2015). A review of the literature for both brain research and STEM implementation reveals that the adolescent years are a prime period of time in a student's life during which they are significantly impressionable and open to the nontraditional methods of learning that STEM education provides (Steinberg, 2012).

Due to the stage of their brain development, students are particularly influenced by their teachers and their teachers' attitudes toward the subjects they teach (Bates, 2014). Because of the importance of STEM to today's K-12 education system and business community, there is a need for continued research in this area as well as for focus studies on how STEM learning can be implemented well with adolescents.

Statement of the Problem

Due to the nature of the Information Age, the demand for professionals (and future professionals) to enter STEM careers has experienced significant growth in the past few years and is projected to increase exponentially. The U.S. Bureau of Labor Statistics indicated that STEM occupations currently hold over 6% of all employment in the nation, and over 60% of all employment in computer systems, architecture, software publishing, and scientific research (Fayer, Lacey, & Watson, 2017). Between 2009 and 2015, STEM occupations grew by over

10%, which is significant in comparison to the 5% of overall job growth in non-STEM fields (Fayer et al., 2017). Workers in nearly all STEM areas earn wages well above the national average (Fayer et al., 2017).

Because of the need to equip a significantly higher number of workers for STEM occupations, a heightened demand for focus on STEM initiatives exists in K-12 education (Achieve, 2013; Brown et al., 2016; Michael & Alsup, 2016; Vasquez, 2015). More students should be exposed to STEM learning in order to cultivate their interests in STEM occupations. Additionally, a significant underrepresentation of females and racial minorities exists in STEM fields, so a targeted focus on these groups in particular is needed (Diekman, Steinberg, Brown, Belanger, & Clark, 2017; Fouad & Santana, 2017).

Brain research literature indicated that adolescence is the optimal point in a student's growth and development for exposure to STEM learning (Steinberg, 2011). It is at this point in time that an adolescent's brain is changing in significant ways, priming them for a very impressionable stage in life (Griffin, 2018). They are easily influenced by their teachers and collaborative learning with their peers and are more open to risks in learning, which aligns well with the trial and error nature of authentic STEM education (Steinberg, 2012).

Statement of Purpose

The overall purpose of this three-article dissertation was to explore the influence of a STEM program on adolescents' confidence in and attitudes toward STEM subjects and interest in STEM careers. The researcher was interested in how the program influenced students' confidence in and attitudes toward STEM, how the program impacted teachers' self-efficacy in STEM, whether teacher self-efficacy of STEM and preparation for a specific STEM program influenced their students' confidence in and attitudes toward STEM, whether differences existed in gender and race in regard to confidence in and attitudes toward STEM, and how groups of female and minority students' confidence in and attitudes toward STEM compared.

Significance of the Study

STEM has become an important area of focus in K-12 education, but there is no consistency in the implementation of STEM with students (Russell et al., 2015; Wu-Rorrer, 2017). No exemplary model of success has yet been developed (Mitts, 2016; Russell et al., 2015; Wu-Rorrer, 2017). This study is important because it can add to the knowledge base of STEM education, and it can provide results on the use of a specific STEM program, including explicit professional development on Sphero, Cubelets, Little Bits, and Lenovo Android tablets. The results of this study can inform researchers and practitioners in the K-12 community about students' and teachers' perceptions of and experiences with this specific STEM-related equipment. Additionally, although STEM is an important area of focus in primary, secondary, and postsecondary education today, females and minorities remain underrepresented in STEM occupations (Bieri Buschor, Berweger, Keck Frei, & Kappler, 2014). Additional research is warranted that focuses on the learning needs and interests of these special groups at the adolescent level.

Theoretical Framework

The three studies are grounded in the theory of situated learning cognition. Situated learning cognition is the belief that "knowledge is situated, being in part a product of the activity, context, and culture in which it is being developed and used" (Brown, Collins, & Duguid, 1989, ¶ 1). The construction of authentic knowledge is closely connected to learning by doing as well as learning within authentic context. True knowledge and growth in STEM fields will come from true and contextual experience with STEM in the formative adolescent years.

Research Methods

This mixed methods dissertation includes three articles examining various aspects of the influence of a STEM program on adolescents' confidence in and attitudes toward STEM. The data used in this study are historical data, existing as a result of surveys administered as part of the evaluation of a STEM program grant awarded to the school district. The STEM program, implemented in a public school district over 4 months, was the result of a grant awarded to the district to promote STEM learning in 6th grade students. The school district pursued the grant because of the need for STEM education.

The first article investigates teachers' self-efficacy in STEM and the influence of teacher preparation and STEM efficacy on students' confidence in and attitudes toward STEM. These were addressed through quantitative analysis of teacher and student surveys as well as through qualitative analysis via open-ended survey questions of teachers. The second article investigates how groups of students' confidence in and attitudes toward STEM compared before and after participating in specific STEM activities, and was addressed through quantitative analysis of pre- and post-surveys. The third article investigates how a specific STEM program influenced female and minority students' confidence in and attitudes toward STEM and was addressed through quantitative analysis of pre- and post-surveys. IRB approval was requested and granted for the studies (see Appendix A).

Instrumentation

There were three primary methods of instrumentation for the studies in this dissertation. The first (T-STEM) was an instrument designed by the North Carolina State University's Friday Institute to measure teachers' STEM efficacy. The original T-STEM instrument as created by the Friday Institute included 56 items. Because the school district considered 55 items too laborious for teachers, they reduced the T-STEM survey items to 32. The revised T-STEM instrument can be seen in Appendix B. The T-STEM was administered to teachers before and after their implementation of the STEM program.

The second instrument used in this dissertation was the S-STEM. The S-STEM was also designed by the Friday Institute to measure students' confidence in and attitudes toward STEM. The original S-STEM instrument included 56 items, which the district also considered too strenuous for 6th graders to complete to fidelity. To avoid survey fatigue, the district reduced the number of survey items on the S-STEM to 25. The revised S-STEM instrument can be seen in Appendix C. The S-STEM was administered to different groups of students before and after their participation in the STEM program.

The Cronbach Alpha statistical test was used in each study to determine the internal consistency and reliability of the modified T-STEM and S-STEM instruments. When the Friday Institute granted the district permission to use the instrument, it also granted the district permission to make modifications to it. Permissions to use and modify the T-STEM and S-STEM instruments can be seen in Appendix D.

The final instrument used in this dissertation was the Follow-Up Teacher Survey that was written by the district with nine items total. Seven of the nine items were open-ended questions. The Follow-Up Teacher Survey can be seen in Appendix E.

Assumptions of the Study

This research study was centered on these assumptions: (a) all teacher and student participants responded in truth to all survey questions, (b) every school had access to identical kits of STEM equipment, (c) every school had access to the same number of teachers trained, (d) all student participants received exposure to and interaction with the STEM equipment provided by the district, and (e) all science, technology, and math teachers made attempts to use the STEM equipment and training provided by the district.

Limitations of the Study

The limitations of this research study were (a) the data were historical; (b) all survey data were de-identified, which prohibited pairing of student responses (paired responses could provide different results); (c) there was an imbalance in student responses on the T-STEM pre- and post-surveys (equalized responses could provide different results); (d) individual teachers' prior knowledge of the STEM equipment varied before the program; (e) individual teachers had no input in the STEM equipment that was purchased for them; (f) the teacher and student survey instruments were modified by the district; and (g) the open-ended survey items could have been more effectively administered in an interview setting rather than in an online form.

Operational Definitions of Terms

Cubelets: In this research study, Cubelets are sets of 5-8 cubes that can be attached to each other in a variety of ways. Each cube is created with a unique purpose, such as sight (camera), sound (speaker), or motion (wheels). Cubelets can be used to develop a combination of robotics, coding, and circuitry skills.

Google Classroom: In this research study, Google Classroom is an online learning management system used to digitally group and connect the participating teachers as a professional learning community.

Lenovo Tablets: In this research study, Lenovo Tablets are Android devices that can be used as a Tablet or as a way to control the Sphero robots using the Sphero app, school wifi, and Bluetooth technology.

Little Bits: In this research study, Little Bits are kits with small pieces of wire, transmitters, receivers, and more to enable students to learn about circuitry by connecting the pieces in a variety of ways.

Middle School Participants: In this research study, middle school students included students in the 6th, 7th, and 8th grades. Middle school teachers included teachers who teach students in the 6th, 7th, and 8th grades.

Science, Technology, Engineering, and Math (STEM): Authentic, problem-based learning that crosses science with two or more other categories of Technology, Engineering, and Math (Hoeg & Bencze, 2017a; Kelley, 2012).

Sphero robots: In this study, Sphero robots are spherical robots with a 4-inch diameter. The Spheros can be coded using the Sphero app installed to a device and connected using Bluetooth technology. Users can drive the Spheros around the room using a digital joystick feature but can also calculate and test computer code to program the devices to independently execute a command.

STEM Kits: In this research study, the STEM kits are identical boxes for each school which include Spheros, Little Bits, Cubelets, and Lenovo Tablets.

Team Drive: In this research study, Team Drive (Google) refers to the shared cloud storage space where participating teachers could find and contribute resources to integrate STEM learning using the equipment provided by the district.

Summary

K-12 education, the national business community, and the future economy of our country are expectant for a focus on STEM learning in schools. This research study investigated the overall influence of a STEM education program in a large southeastern public school district, with specific attention to a variety of components.

This three-article dissertation consists of five chapters. Chapter I states the overall purpose of the study, explains why the study is significant, describes the theoretical framework, and describes the three articles. Chapter II is the first article concerning teacher efficacy in STEM, whether a difference exists in teacher types regarding STEM efficacy, and how teacher preparation for a specific STEM program impacts students' confidence in and attitudes toward STEM. Chapter III is the second article concerning how groups of students' confidence in and attitudes toward STEM compare before and after a specific STEM program. Chapter IV is the third article concerning how a specific STEM program influences female and minority students. Chapter V concludes by summarizing and discussing the research, considering the implications, and making recommendations for further study.

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CHAPTER II

THE INFLUENCE OF TEACHER EFFICACY AND PREPARATION ON STUDENTS IN A STEM PROGRAM

Confidence Matters

The goal of this district's STEM program was to increase teachers' self-efficacy in STEM and students' confidence in their own STEM ability. Self-efficacy is defined by Bandura (1977) as "the conviction that one can successfully execute the behavior required to produce outcomes" (p. 193). The amount of self-efficacy an individual has in any subject or task can determine their level of determination to persevere despite barriers to success (Bandura, 1977). Students will neither pursue nor enjoy STEM learning without healthy confidence in these areas (Brown et al., 2016; Nadelson et al, 2013). While most gains in implementing successful STEM education programs occur at the local level, it can be challenging to make significantly progressive change in STEM learning due to the vague nature of the field as a whole (Sondergeld, Johnson, & Walten, 2016).

Teachers can make a significantly positive impact on students' confidence in STEM areas when they themselves have a healthy self-efficacy in STEM areas (Annetta et al., 2012). When teachers of science are willing to improve their instructional strategies and their confidence in teaching, that efficacy is passed along to students, who reap the benefits of increased confidence in learning about and participating in science (Annetta et al., 2012). Likewise, if teachers are poorly equipped or if the intricacies of STEM learning are not considered, the outlook for successful STEM education will be poor (Kelley, 2012). It is essential for instructional leaders to advocate for professional development funding as a priority for STEM initiatives (Zuger, 2012).

Setting

The setting for this study was a public school district which serves approximately 21,000 students in the southeastern United States (population information from district website). The study specifically focused on Grade 6 in the seven middle schools across the district, referred to throughout as Schools A-G. Collectively, the seven middle schools serve approximately 1300 6th grade students. Though all schools serve grades 6-8, they vary demographically and socioeconomically. The differences in population, race, gender, and free/reduced lunch status are seen in Table 2.1. Free/Reduced lunch status is an indication of poverty level in the community served by a school. Information for Table 2.1 was sourced from the district as well as schools' and community websites.

Purpose of the Study

The purpose of this study is to investigate whether a STEM program impacts teachers' self-efficacy in STEM, whether a difference exists in teacher types (i.e., science, math, technology) regarding STEM efficacy, and the influence of teacher preparation and efficacy in a STEM program on students' confidence in and attitudes toward STEM.

Research Questions

The research questions for this study are

Research Question 1: Does teacher self-efficacy of STEM influence students' confidence in and attitudes toward STEM?

Null Hypothesis: Teacher self-efficacy of STEM does not influence students' confidence in and attitudes toward STEM.

Table 2.1

Comparison of School Demographics

School	Population	Race	Gender	Free/Reduced Lunch
School A	328	White: 51% Black: 31% Hispanic/Latinx: 16.5% Biracial/Other: 1.5%	Male: 51% Female: 49%	64%
School B	432	White: 81.7% Black: 12% Hispanic/Latinx: 4.9% Biracial/Other: 1.4%	Male: 49% Female: 51%	56%
School C	1007	White: 86.7% Black: 7.1% Hispanic/Latinx: 3.7% Biracial/Other: 2.5%	Male: 51% Female: 49%	16%
School D	1109	White: 75.3% Black: 11% Hispanic/Latinx: 6.8% Biracial/Other: 6.9%	Male: 52% Female: 48%	15%
School E	457	White: 72.6% Black: 23.6% Hispanic/Latinx: 1.5% Biracial/Other: 2.3%	Male: 52% Female: 48%	63%
School F	668	White: 56% Black: 33.2% Hispanic/Latinx: 7.8% Biracial/Other: 3%	Male: 50% Female: 50%	45%
School G	964	White: 78.8% Black: 12% Hispanic/Latinx: 4.1% Biracial/Other: 5.1%	Male: 50% Female: 50%	18%

Research Question 2: Will there be a difference based on teacher type in teachers' self-efficacy in STEM?

Null Hypothesis: There will not be a difference based on teacher type in teachers' self-efficacy in STEM.

Research Question 3: Does teacher efficacy in STEM change after participating in a STEM program?

Null Hypothesis: There will be no change in teachers' self-efficacy in STEM after participating in a STEM program.

Research Question 4: What are the keys to a STEM program's successful implementation district-wide?

Theoretical Framework

This study was structured around the theory of situated learning cognition. Situated learning cognition establishes the connection between genuine knowledge and use within context (Brown et al., 1989). True knowledge is created through experiential learning, which can include the acquisition of new knowledge as well as the construction of the learner's agency or ability to test their new knowledge (Riveros, Newton, & Burgess, 2012).

The STEM program investigated in this study included teachers' active learning through professional development training in the use of Sphero robots, Little Bits circuitry kits, Cubelets modular robotic/circuitry sets, and Lenovo Android Tablets with which to run the Sphero. True knowledge of STEM and positive changes in STEM self-efficacy for teachers come from authentic, contextual experiences with STEM professional development. This leads to students' true knowledge of STEM and positive changes in STEM self-efficacy. This study explored teachers' self-efficacy before and after the STEM program, differences in teachers' STEM self-efficacy by teacher type, and the connection between teacher preparation and self-efficacy in

STEM and students' confidence in and attitudes toward STEM after participating in a specific STEM program.

Overview of the Literature

Building STEM Self-efficacy in Teachers

Professional development, or training of in-service teachers to build their instructional aptitude, is considered one of the most influential measures to positively impact student learning (Bates & Morgan, 2018; Battersby & Verdi, 2015; Bayar, 2014; Desimone, 2011; DiPaola & Hoy, 2014; Lutrick & Szabo, 2012). One way to build instructional aptitude of teachers is to increase their self-efficacy in the content areas they teach (Parsons, Ankrum, & Morewood, 2016). Self-efficacy, or teachers' beliefs about their abilities, is nurtured by the acquisition of knowledge and the autonomy to make decisions using that knowledge (Joo, Park, & Lim, 2018; Parsons et al., 2016).

Effective professional development increases teachers' knowledge about their subjects and confidence in their ability to teach those subjects to their students (Gomez Zwiep & Benken, 2013; Lutrick & Szabo, 2012; Rosen, 2012). There is no perfectly prescriptive protocol for effective professional development, but researchers agree on the relevant inclusion of factors such as being continuous, collaborative, interactive, and job-embedded, based on research and data, and networking learners within a professional learning community (Battersby & Verdi, 2015; Bayar, 2014; Boylan & Demack, 2018; Desimone, 2011; DiPaola & Hoy, 2014; DuFour, 2014).

According to Zuger (2012), nearly half of teachers responding to a survey about STEM indicated inadequate professional development as a leading challenge facing STEM education efforts nationwide. The type of professional development instruction required for successful

STEM education significantly differs from how most teachers are trained, because STEM learning is a very different type of learning from traditional subjects (Rosenzweig & Wigfield, 2016). Traditional instruction leans toward a less yielding design, while STEM learning is more fluid and based on experiential inquiry, reflection, and collaboration (Bayar, 2014; Frerichs, Fenton, & Wingert, 2018). The instructional activities in effective STEM professional development must be appropriately challenging and within the participants' zone of proximal development (Gomez Zwiep & Benken, 2013; Nazier, Sinclair, & Szabo, 2017). STEM learning is adaptive learning; likewise, the instructional model for STEM professional development is also adaptive rather than rigidly recursive in nature (Nadelson et al, 2013; Parsons et al., 2016; Patton, Parker, & Tannehill, 2015).

One key to effective STEM professional development is modeling the use of both the materials and the methods that exemplify best instructional practices (Annetta et al., 2012). Best practices in professional development for teachers in using technology to teach science includes active and hands-on learning and modeling instructional pedagogy with the available resources teachers are expected to use (Annetta et al., 2012; Bates & Morgan, 2018). Instructors should take care to model the integration of technology resources in particular so that teachers feel comfortable with them and understand how to use them with their students and existing curriculum (Bates & Morgan, 2018). Although most STEM learning is collaborative, educators are aware that instructional technology continues to evolve, and some students may benefit from web-based resources that provide them with the option of self-paced avenues of exploration in STEM subjects (Storksdieck, 2016). Making teachers aware of the options and resources available can help build their confidence in supporting their students.

An emphasis on the use of inquiry is specifically helpful to supporting teachers as they find their footing with STEM teaching (Nadelson et al., 2013). The instructional model for effective STEM professional development should support significant autonomy for teachers, as greater self-sovereignty and professional choice can facilitate more transformative change in behavior (Boylan & Demack, 2018; Parsons et al., 2016). Professional development must also be clearly relevant to teachers' curriculum and include a relationship of ongoing support in implementing the new strategies (Annetta et al., 2012). STEM-focused professional development should provide ample support for teachers through exposure to new resources and strategies, but also to a community of their colleagues based on trust and mutual respect so that they can collaboratively work through both successes and failures (Parsons et al., 2016; Patton et al., 2015; Pella, 2015).

The stakes are high with supporting STEM education through high quality professional development. As stated by Kelley (2012), "If researchers of STEM fail to thoroughly investigate the complexities surrounding teacher practices that integrate STEM, the recent efforts to infuse STEM education into the classroom will be void" (p. 35). Conversely, when teachers are properly supported with strategies and questioning skills to facilitate students' investigations, collaborative work, and reflections, their students' experience with STEM learning will be positive (Nadelson et al, 2013; Pella, 2015; Satchwell & Loepp, 2002; Wentzel, 2009).

STEM Self-efficacy: The Relationship Between Teachers and Students

A full and proper understanding of students' beliefs about themselves and their STEM capacity can direct instructional leaders to the best strategies and involvement that will preserve higher numbers of students interested in STEM occupations (Shoffner, Newsome, Barrio Minton, & Wachter Morris, 2015). When teachers are aware that students' perceptions of and confidence in their ability to do mathematics can be a deciding factor in a students' success with STEM, they can make efforts to promote healthy confidence in mathematics in all their students (Watt et al, 2017).

Methods

The purpose of this study was to investigate whether there is a change in teachers' self-efficacy after a STEM program, whether a difference regarding STEM efficacy exists in teacher type, and how teacher preparation and self-efficacy of STEM influence their students' confidence in and attitudes toward STEM after implementation of a specific STEM program. The STEM program, implemented in a large southeastern public school district over 4 months, was the result of a grant awarded to the district to promote STEM learning in 6th grade students. The district technology leadership pursued the grant because of the need for STEM education in general as well as the specific call for a focus on the impressionable 6th grade year. Research indicating a widening gap of both interest and performance between races and gender in STEM areas also played a motivating role in the submission of the grant application (Muller, Stage, & Kinzie, 2001). The district technology leadership included a technology supervisor, specialist, and technology coaches. The equipment included in the grant application were Spheros, Little Bits, Lenovo tablets, and Cubelets. The teachers in the STEM program were not involved in selecting the equipment.

Once awarded grant funding, the district purchased items and formed kits of STEM-focused equipment that were disseminated to 6th grade science, technology, and math teachers. Included in the kits were the Spheros, Little Bits, Lenovo tablets, and Cubelets that were included on the grant application for the STEM program. Spheros are round robotic balls that can be controlled remotely using a linked app on a smartphone or tablet. The Lenovo Android tablets were included in the kits for teachers and students to use to run and code the Sphero. Students could use drag and drop Blockly coding to write programs made up of a series of actions the Sphero performs once the code is launched. Students test and retest, working through angles, distances, and behaviors in order to program the Sphero robot to achieve certain goals such as navigating a maze or other challenges. Little Bits are sets of magnetic circuitry pieces with which students can experiment to create a variety of devices such as alarms, timers, musical instruments, signal regulators, fans, and buzzers. The Cubelets are considered a modular robotics set. Each cube in a set is designed with a certain sense (power, sight/camera, light, movement, etc.) and through experimentation students can use Cubelets to learn how robots function as they build them in a variety of ways. Each school's kit contained Spheros, Cubelets, and Little Bits as well as a Lenovo Android tablet with which to run the Spheros devices.

The equipment was one portion of the STEM program. The other piece was the implementation plan and support from the district for teachers. The 6th grade math, technology, and science teachers from each school were provided a substitute and invited to the central office for an explanation of the program. During this initial meeting, the district informed teachers of the grant, shared research on the need for a focus on STEM learning in 6th grade, and provided teachers with hands-on opportunities to experiment with and learn the equipment in their kits. The *Teacher Efficacy and Attitudes Toward STEM Surveys* (T-STEM Pre) were then administered to teachers. The teachers were also added to a group Google Classroom space and Team Drive where they could search for and add lessons relevant to their STEM efforts. Shortly after the teachers' professional development, the district sent out the *Student Attitudes Toward STEM Survey—Middle and High School Students* (S-STEM) for teachers to post for their 6th grade students. The S-STEM pre-surveys were administered through the technology courses in

February 2018 and resulted in 286 responses. The same surveys (S-STEM Post) were administered again in May 2018 and through the same technology courses and resulted in 470 responses. In this district, 6th grade students rotate through different electives each quarter, so the students surveyed in February were different from those surveyed in May. Participation varied across schools. The T-STEM post-survey was sent to teachers in May 2018, and a final follow-up survey was sent to teachers in May 2018 as well to gather their input on their experiences with and feelings about the program.

The theory of situated learning cognition shows that authentic learning cannot be detached from its use (Brown et al., 1989). This framework for the study provided a foundational function in the data collection and analysis process, because any changes in students' confidence in and attitudes toward STEM before and after the program is implemented could occur if the students truly experienced each portion of the program. The students could only truly experience each portion of the program through their participation in activities designed by their teachers. Their teachers could design the active learning lessons only after they were trained in the effective use of the specific equipment used in this STEM program, including Sphero, Little Bits, Lenovo Android Tablets, and Cubelets. The research questions on changes in teachers' self-efficacy in and attitudes toward STEM were investigated both quantitatively and qualitatively. The research questions regarding differences in teacher types and the influence of teacher preparation and STEM efficacy on students' confidence in and attitudes toward STEM were addressed through quantitative analysis of T-STEM and S-STEM surveys as well as through qualitative analysis of teacher responses to their follow-up survey.

Participants

This study used historical data collected from 6th grade science, math, and technology teachers (including librarians) and their students. All 6th grade students in the school district were participants in the STEM program. The data used in this study were historical data, existing as a result of surveys administered as part of the evaluation of a STEM program grant awarded to the school district.

Instrumentation

The instruments for this study were designed by the North Carolina State University's Friday Institute (2012) to measure teachers' STEM efficacy and students' confidence in and attitudes toward STEM. The original T-STEM instrument created by the Friday Institute to measure teachers' STEM efficacy included 56 items. Because the school district considered 56 items too laborious for teachers, they reduced the T-STEM survey items to 32. The revised T-STEM instrument can be seen in Appendix B. The T-STEM was administered to teachers before and after their implementation of the STEM program.

The second instrument used in this dissertation was the S-STEM. The S-STEM was also designed by the Friday Institute (2012) to measure students' confidence in and attitudes toward STEM. The original S-STEM instrument included 56 items, which the district also considered too strenuous for 6th graders to complete to fidelity. To avoid survey fatigue, the district reduced the number of survey items on the S-STEM to 25. The revised S-STEM instrument can be seen in Appendix C. The S-STEM was administered to different groups of students before and after their participation in the STEM program.

When the Friday Institute granted the district permission to use the instrument, it also granted the district permission to make modifications to it. Permissions to use and modify the T-

STEM and S-STEM instruments can be seen in Appendix D. The Cronbach Alpha statistical test was used in each study to determine the internal consistency and reliability of the modified T-STEM and S-STEM instruments.

Both the T-STEM and S-STEM were selected from North Carolina State University's Friday Institute (2012) because they were reported as valid and reliable surveys and "demonstrated evidence of configural, metric, and scalar invariance across grade levels, races/ethnicities, and genders" (Unfried, Faber, Stanhope, & Wiebe, 2015, p. 15). The S-STEM and T-STEM surveys were also selected by the study's school district because they were already existing, had been used successfully with other STEM programs, and were free. The Friday Institute granted the school district permission to use and edit the survey instruments. This permission is seen in Appendix D. There are four surveys total. The S-STEM Survey is for students and appears in Appendix C. The T-STEM Survey is for teachers, and there is a unique survey for each of the three areas of science, math, and technology. These surveys appear in Appendix B. The district added two open-ended questions to the T-STEM to gather teachers' thoughts on their concerns regarding the specific STEM equipment before and after they implemented the STEM program. These items are also included in Appendix B. Additionally, a follow-up survey with open-ended questions was conducted with the teacher participants in the 4th month of the program. The items in this survey appear in Appendix E.

Researcher Positionality

This is a mixed methods explanatory sequential study. As a school librarian in this district, the researcher served the instructional technology team in their implementation of the STEM program. This included recommendation of the survey instruments. The researcher also attended the initial professional development workshop, led demonstration and hands-on exploratory sessions of the STEM equipment provided by the grant, observed the interactions among participating teachers, and provided support for teachers as they sought to implement best practices in STEM education for their students. Throughout this process, the researcher acted as an observer and, at times, a participant to nurture teachers' STEM self-efficacy by understanding the need for STEM education as well as becoming comfortable with the grant-provided equipment.

School librarians in this district are encouraged to serve as STEM leaders within their schools. As a result of developing makerspaces, writing STEM grants; researching trends in STEM education; designing collaborative lessons incorporating math, science, engineering, and math; and launching a school-wide STEM fair, the researcher is an advocate for and has a bias toward cultivating STEM learning and leadership in all grade levels across the K-12 spectrum. Efforts were made when interpreting and coding teacher responses and comments to retain an open mind and to view the practicalities of the STEM program from each teacher's point of view.

Because gender, race, and socioeconomic status can cultivate biases, the White, middle class, female researcher was cautious about taking a multidimensional approach to the outcome of every analysis. Multiple perspectives were considered to provide a full picture of the teachers, students, teachers' positions, and their schools.

Data Collection

Because the STEM program was grant-funded, the school district needed to evaluate its effectiveness. The T-STEM (Pre) was given to teachers at the initial professional development workshop provided by the district in February 2018. The T-STEM (Post) was again sent out to all teacher participants in May 2018. A final follow-up survey with open-ended questions was conducted with the teacher participants in the 4th month of the program. This survey was sent to teachers in May 2018. The S-STEM (Pre) student surveys were administered during their technology classes in February 2018, and a second round of S-STEM (Post) survey data was collected in May 2018. In this district, 6th grade students rotate through different electives each quarter, so the students surveyed in February were different from those surveyed in May. Participation varied across schools.

Data Analysis

Multiple methods were used to examine the effectiveness of the STEM program for teachers and students. First, the teachers' self-efficacy in STEM, students' confidence in and attitudes toward STEM, and differences across teacher types were analyzed quantitatively. Then, the teachers' views of, experiences with, and concerns about the STEM program were evaluated qualitatively, where the phenomenological concept of the keys to a successful STEM program emerged.

To address Research Question 1, the T-STEM pre- and S-STEM post-surveys were compared quantitatively through a correlation analysis. The significance level for all tests conducted was .05. To address Research Question 2, the T-STEM Teacher survey was compared across teacher types (science, technology, and math) through a one-way ANOVA. To address Research Question 3, a paired or dependent *t*-test was conducted to compare the teachers before and after their implementation of the STEM program. To address Research Question 4, the teachers' open-ended responses to Items 31 and 32 on the T-STEM pre- and post-surveys as well as teachers' responses to the follow-up survey were reviewed qualitatively through the constant comparative method of content analysis. An emergent thematic coding scheme was developed to determine trends across teacher responses.

Results

The sample size for the T-STEM pre-survey was 20. This included eight science teachers, six technology teachers, and six math teachers. The T-STEM pre survey group of teachers was comprised of 40% science, 30% technology, and 30% math. There are seven middle schools in the district, all represented within the T-STEM pre-survey group of teachers. School E had the highest number of teachers present at the training at 20%, while schools B and F had the lowest at 10% each. This can be seen in Table 2.2.

Table 2.2

T-STEM Pre-survey Participation by School

	Frequency	Percent	Valid Percent	Cumulative Percent
A	3	15.0	15.0	15.0
B	2	10.0	10.0	25.0
C	3	15.0	15.0	40.0
D	3	15.0	15.0	55.0
E	4	20.0	20.0	75.0
F	2	10.0	10.0	85.0
G	3	15.0	15.0	100.0
Total	20	100.0	100.0	

The sample size for the T-STEM post-survey was 12. This included five (4.17 %) science teachers, two (16.7%) technology teachers, and five (41.7%) math teachers. The technology group included computer teachers as well as school librarians. There are seven middle schools in the district, each represented within the T-STEM post survey group of teachers. School C had the highest number of teachers respond to the survey at 25% of the total respondents, while school E had the lowest at 8.3%. This can be seen in Table 2.3.

The sample size for the S-STEM (post) survey was 470. This sample represented 6th grade students in seven different middle schools within the district. There was a variety of representation across the seven schools, with School F having the lowest percentage at 1.5% and School B having the highest percentage at 29.8%. These can be seen in Table 2.4.

Table 2.3

T-STEM Post-survey Participation by School

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	2	16.7	16.7	16.7
	B	2	16.7	16.7	33.3
	C	3	25.0	25.0	58.3
	E	1	8.3	8.3	66.7
	F	2	16.7	16.7	83.3
	G	2	16.7	16.7	100.0
	Total	12	100.0	100.0	

Table 2.4

S-STEM Post-survey Participation by School

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	93	19.8	19.8	19.8
	B	140	29.8	29.8	49.6
	C	108	23.0	23.0	72.6
	D	24	5.1	5.1	77.7
	E	59	12.6	12.6	90.2
	F	7	1.5	1.5	91.7
	G	39	8.3	8.3	100.0
	Total	470	100.0	100.0	

Of the 470 6th grade respondents, 229 (48.7%) were male and 225 (47.9%) were female. Sixteen (3.4%) students indicated that they preferred not to answer the gender question on the survey. Of the 470 participants, 332 (71%) were White, 53 (11%) were Black, 47 (10%) were Hispanic/Latinx, and 38 (8.1%) were considered Other. The “Other” category was collapsed to include Biracial, Native American, and Asian/Pacific Islander. The original S-STEM survey instrument from the Friday Institute (2012) contained 56 items, and the original T-STEM contained 63. The district elected to reduce the number of items on both the S-STEM and T-STEM to protect students and teachers from survey fatigue. The modified S-STEM survey contained 25 items, while the modified T-STEM contained 30 items. Items 2 and 8 on the S-STEM were reverse coded due to negative wording. The S-STEM pre-survey had a reliability coefficient using Cronbach's alpha of .817, and S-STEM post-survey had .821. The T-STEM pre-survey had a .788 reliability coefficient, and T-STEM post-survey was .908. These indicated strong internal validity and reliability for the modified survey instruments.

Research Question 1

The first research question asked whether there is a relationship between teachers' self-efficacy in STEM and students' confidence in and attitudes toward STEM. The T-STEM pre-survey and S-STEM post-survey were used to answer this question. The T-STEM pre-survey (see Appendix B) was made up of 30 questions with two sets of Likert-type responses for the items. Responses for 17 of the survey items were 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. The remaining 13 items were answered with a different Likert-type scale including the following responses: 1 = Never, 2 = Occasionally, 3 = About Half the Time, 4 = Usually, and 5 = Every Time. There were two open-ended questions added to the T-STEM that were not included in the quantitative analysis of this survey. The S-STEM post-survey (see Appendix C) was made up of 25 questions, all of which were answered using a 5-point Likert scale. Response options for the S-STEM were 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. Two of these 25 items were reverse coded due to negative wording.

A scatterplot was generated to determine the linear relationship and to detect outliers within the data sets. Because the scatterplot indicated a violation of the linearity assumption for the Pearson's correlation coefficient, the Spearman's correlation coefficient was used as a non-parametric measure to determine whether a relationship existed between the variables of teacher efficacy and students' confidence in and attitudes toward STEM. There were two assumptions for this test. The first assumption was that both variables were ordinal. This was met because both the T-STEM and S-STEM included Likert-type scale responses. The second assumption was that there is evidence of a monotonic relationship, even with outliers. The Spearman correlation coefficient is not considered to be significantly affected by outliers (Field, 2013). Both of these assumptions were met.

The Spearman correlation indicated a p-value of .199. Because $p > \propto (.05)$, the null hypothesis was not rejected. There was no significant relationship between the teachers' self-efficacy in STEM and the students' confidence in and attitudes toward STEM.

The teacher (n=20) mean was 109.3 with a standard deviation of 9.217 and the student (n = 470) mean was 83.25 with a standard deviation of 11.465. A higher average/mean in teacher responses indicates that the teachers had a higher level of confidence in STEM than the students. The students' higher standard deviation indicates a wider variety in student responses than those of the teachers.

There are many possible explanations for these results. The teachers completed their surveys at the end of a workshop where they were actively using and designing collaborative lessons on the STEM equipment they were being given by the district. After a full day of STEM training, they were likely at a professional high level in STEM self-efficacy. The students would likely have completed their surveys at the end of their technology classes and in isolation from immediate or recent practical application of the STEM equipment. The inconsistency in student responses could indicate a lack of consistency in survey administration across the district.

Research Question 2

The second research question asked whether there is a difference based on teacher types (science, technology, and math) in teachers' self-efficacy in STEM. The T-STEM pre-survey was used to answer this question. The T-STEM pre-survey (see Appendix B) consisted of 30 questions with two sets of Likert-type responses for the items. Responses for 17 of the survey items were 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. The remaining 13 items were answered with a different Likert-type scale including the following responses: 1 = Never, 2 = Occasionally, 3 = About Half the Time, 4 = Usually, and 5 = Every Time. There were two open-ended questions added to the T-STEM that were not included in the quantitative analysis of this survey.

The three T-STEM teacher type categories of science, technology, and math were independent samples. Homogeneity of testing was met for a one-way ANOVA with an insignificant Levene statistic of .146. The one-way ANOVA comparing teacher types indicated a p-value of .025. Because $p < \propto$ (.05), the null hypothesis was rejected. There was a significant difference between teacher types regarding self-efficacy in STEM. Means and standard deviations by teacher type can be seen in Table 2.5.

Technology teachers indicated a higher self-efficacy in STEM than science and math teachers, with math teachers having the lowest self-efficacy in STEM. There was a significantly different level of STEM self-efficacy between technology and math teachers. Those differences can be seen in Table 2.6. The technology teachers group included technology teachers and school librarians, who are the leaders within each school to implement makerspaces in libraries and classrooms. Their content areas require collaboration, so they are experienced in collaborative teaching and often have greater access to STEM funding and resources than other teachers. Professional development activities for technology teachers and school librarians in this district are often, if not always, geared toward STEM integration across the curriculum.

Table 2.5

Teacher Means and Standard Deviations

Total	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean: Lower Bound	95% Confidence Interval for Mean: Upper Bound	Minimum	Maximum
Science	8	111.63	9.471	3.348	103.71	119.54	94	121
Technology	6	114.17	3.545	1.447	110.45	117.89	110	119
Math	6	101.33	8.454	3.451	92.46	110.21	95	116
Total	20	109.30	9.217	2.061	104.99	113.61	94	121

Table 2.6

Multiple Comparisons Between Teacher Types

(I) Teacher Type	(J) Teacher Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval: Lower Bound	95% Confidence Interval: Upper Bound
Science	Technology	-2.542	4.240	.822	-13.42	8.34
	Math	10.292	4.240	.065	-.59	21.17
Technology	Science	2.542	4.240	.822	-8.34	13.42
	Math	12.833*	4.533	.029	1.20	24.46
Math	Science	-10.292	4.240	.065	-21.17	.59
	Technology	-12.833*	4.533	.029	-24.46	-1.20

*. The mean difference is significant at the 0.05 level.

According to the survey data, math teachers tended to be the most isolated within the school community in this district. At this point in time, they did not have much experience collaborating with other content areas and were focused on mathematical skills and models. This was indicated by these math teachers' statements: "I have not included many investigations that included Science and Technology," "This is a new adventure for me," and "I am not familiar with STEM activities because I have only been trained in [state math curriculum] in the past." Their low level of STEM efficacy in this study can be explained by their recent introduction to learning about STEM education. Math teachers indicated that this was a very new way of teaching for them. Science teachers, however, were very open to collaboration and students' use of technology to investigate and experiment. Their responses to the T-STEM surveys included many specific STEM activities they had already attempted with their students such as constructing and testing earthquake structures, building bridges to withstand heavy weights, developing moon and Mars habitats, building functional weather measurement tools, and experimenting with the shaping of foil boats to prevent their cargo from sinking. Given the science teachers' higher level of STEM efficacy, their rank in the STEM self-efficacy order aligned with their existing instructional efforts.

Research Question 3

The third research question asked whether teacher efficacy changed after participating in the STEM program. The T-STEM was given pre and post and the results were used to answer this question. The T-STEM Survey (see Appendix B) was made up of 30 questions with two sets of Likert-type responses for the items. Responses for 17 of the survey items were 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. The remaining 13 items were answered with a different Likert-type scale including the following responses: 1 = Never, 2

= Occasionally, 3 = About Half the Time, 4 = Usually, and 5 = Every Time. There were two open-ended questions added to the T-STEM that were not included in the quantitative analysis of this survey.

A paired, dependent *t*-test was conducted to investigate Research Question 3. The assumptions for this test, including normality of score distribution, ordinal variable of teacher score, and independent groups were met. This involved matching teacher types and schools to form 12 sets of T-STEM pre- and post-survey results. The analysis of the paired *t*-test revealed that the mean of the teachers' scores before the STEM program was 108.83 with a standard deviation of 10.107, while the mean of the teachers' scores after the STEM program was 110.58 with a standard deviation of 12.026. The paired samples correlation test (N=12), also conducted within the paired *t*-test, indicated a significance level of .030 (r = .624). Because $p < \propto$ (.05), the null hypothesis was rejected. There was a significant change in teachers' self-efficacy in STEM after participating in a STEM program.

Research Question 4

To investigate Research Question 4, teachers' responses from open-ended questions were analyzed qualitatively using the constant comparative method of content analysis. An emergent coding scheme was developed to determine thematic trends across teacher responses. The two open-ended questions added by the district to the T-STEM pre and post survey were

1. In the past, what STEM or STEAM activities have you included in your instruction?
2. What concerns do you have regarding the implementation of the Middle School Coding (STEM) Grant?

There were 20 responses to these questions on the T-STEM pre-survey (February, 2018) and 12 responses on the T-STEM post-survey (May, 2018). All seven middle schools and all three teacher types were represented in the pre and post responses. There were seven responses overall to the open-ended follow-up survey in late May. All three teacher types and six of the middle schools were represented in the follow-up survey responses. The questions on that survey were

1. How have you used the Cubelets?
2. How have you used the Spheros?
3. How have you used the Tablets?
4. How have you used the Little Bits?
5. What struggles have you experienced using this equipment?
6. What would make you more comfortable using this equipment?
7. What successes have you experienced in using this equipment?

To answer Research Question 4 and to supplement the quantitative results from other research questions with the voices of the teacher participants, all teacher responses were analyzed qualitatively using the constant comparative method and emergent coding technique.

Five primary themes emerged while analyzing the teachers' concerns about the STEM program, with three overlapping in the pre- and post-surveys as well as the program follow-up surveys. The three primary themes were

- Time
- Efficacy/Training
- Equipment

The five themes overall were

- Time
- Efficacy/Training

- Equipment
- Curriculum
- Classroom Management

Time. Teachers of all three subject areas mentioned time as their primary concern for implementing the STEM program. Time was mentioned by 14 different math, science, and technology teachers in the T-STEM Pre, T-STEM Post, and follow-up survey responses. They were concerned about sufficient time to plan, implement, learn, and to use/charge/prepare equipment for seven sequential class periods a day. A math teacher struggled with “how this will work in a 45 minute class time and be able to prepare for the next class within 5 minutes.” A science teacher indicated concern over “lack of time due to constant and changing demands on us as teachers.” Another science teacher responded, “I would like more time to collaborate with peers on activities.” A math teacher stated concern over “time management.”

Efficacy/Training. Efficacy/Training ranked as the second most prominent concern of the 6th grade teachers. Their comments indicated a desire for more, deeper, hands-on training so that they would have the confidence to use the equipment in a meaningful way with their students in their subject areas. One science teacher responded, “I just want to make sure I fully know how to use and utilize all of the materials so I can better serve my students.” Another stated simply, “Can I do it?” A third wrote that “[t]eachers need adequate training and knowledge” to implement the STEM program well, and four separate teachers stated a variation of “I need a deeper, more hands-on training.” One science teacher responded, “I would like more time to learn how to use everything and how we can incorporate and use those resources in our classroom.”

Equipment. Though there were a few worries expressed regarding equipment on the T-STEM pre survey, the bulk of equipment-related concerns came from the T-STEM post-survey and follow-up survey. Before the program, two technology teachers made similar remarks that they were concerned about "having enough resources for all students to participate." After the program, however, there were equipment-related concerns from science, technology, and math teachers across the board. Many of their comments were related to specific failures of the equipment—primarily the tablets.

> "The Lenovo Android platform doesn't pair well with the Spheros; thus, the continuity and intended outcome of activities became stressful for me and the kids. Some kids had great luck and then suddenly, they were booted off, while others couldn't get theirs to pair at all." Several others complained that the WiFi was not strong enough or "tends to lose connection.

One teacher wrote,

> The tablets had a hard time connecting to the wifi and bluetooth to connect to the Spheros. Sometimes they would connect and then drop the connection. This made it difficult for students to complete their lesson during the class. I also struggled with supporting students with only enough supplies for 3 groups to work on coding while the rest of my class had to work on a different lesson.

Other than functional issues with the Lenovo Android tablets and finding the Little Bits "hard to use," the primary concern from teachers after implementing the program was related to insufficient volume of equipment in their class kits. In addition to preferring their personal or classroom iPads to the Lenovo Android tablets, they repeatedly indicated a need for more equipment. Several teachers indicated concern about all students having equitable access to the resources. One science teacher stated he/she was "Concerned about ways to use the Sparks [Sphero SPRK], Lil Bits and Cubelets with an entire class, which can have as many as 26 students, and have each student benefit from the hands-on experience."

Curriculum. One area that emerged in analysis of the post-survey and follow-up survey responses was a cry for support in establishing a tighter connection to the science and math content areas with the STEM lessons. “I am concerned about being able to adapt STEAM lessons to content” wrote one science teacher. Other science teachers indicated they needed “[m]ore support/lessons for using the equipment that relates to standards.” A math teacher responded, “How to incorporate the Cubelets into the state standards.” A science teacher indicated struggling with “knowing how to implement them into some of the curriculum to correspond with the standard.” Teachers, especially math and science, needed relevance to warrant their time and energy investment in designing STEM lessons.

Classroom management. Classroom Management was absent from the responses to the T-STEM pre-survey but heavily infused throughout the post-surveys. Math teachers struggled with “Time management” and suggested

> It might be helpful to try to have more items available for more students to be able to work with them. When there is only a small number of items, then there has to be larger groups formed and this can cause discipline issues and each child in the group may feel they can’t really get a chance to explore with that certain item.

A science teacher wrote, “…I also struggled with supporting students with only enough supplies for 3 groups to work on coding while the rest of my class had to work on a different lesson.” There was also a concern from a math teacher about the sustainability of the equipment and time management in using the equipment in sequential lessons throughout the day.

Though the primary portion of the teachers’ responses comprised their concerns and struggles, there were a few positive comments regarding the STEM program. The technology teachers indicated excitement in their T-STEM pre-survey responses, while math and science teachers remarked that “I am not familiar with STEM activities” and “This is a new adventure for me.” Although the Little Bits, Lenovo Android tablets, and Cubelets were negatively described (and received consistent “No” responses from teachers of all subject areas), the Spheros were very highly regarded and positively viewed by all teachers. They indicated their students’ love for and excitement over using Spheros as well as specific content-related lessons they designed, including using Spheros to see the relationship between time, speed, and distance; learning about Newton’s Law of Motion; and coding the Sphero robots to draw out geometric shapes on the floor. Almost all of the teachers’ lessons submitted on their surveys involved the Sphero, and there were several comments about how much their students enjoyed using the equipment.

Discussion and Implications

The themes resulting in this study can also serve as a way to explain the quantitative results from Research Questions 1-3. Results from Research Question 1 indicated that there is not a significant relationship between the teachers’ self-efficacy in STEM and the students’ confidence in and attitudes toward STEM. This could be explained with the teacher responses. Although there was an increase in teachers’ STEM self-efficacy scores after the STEM program, as revealed in an analysis of Research Question 3, the gain was small. The teachers’ comments indicated considerable frustration with the equipment, which may have inhibited their own self-confidence in STEM learning. More success with the equipment may have resulted in greater gains in self-efficacy and confidence in STEM for both teachers and students alike. An analysis of teacher types in Research Question 2 indicated that technology teachers had the highest self-efficacy in STEM while science was second and math last. The teachers’ comments helped explain these results. Divided into teacher type, a clear trend emerged from the technology teachers: excitement and ample experience. These teachers had more familiarity with using technology and STEM equipment before the STEM program began, so it is logical that they would have the highest STEM self-efficacy scores. The math teachers responded with more concerns regarding implementation, equipment, classroom management, and resources than other subject areas. Their STEM self-efficacy scores were lower because they were the newest to the cross-curricular world of STEM learning and therefore carried a significant amount of anxiety about every piece of the program.

The themes that emerged during constant comparative analysis of the teachers' responses can also be used to provide a theory for the keys to successful implementation of a STEM program. The primary themes of Time, Efficacy, and Equipment can provide a framework of priority emphasis for professional development and technology leaders to use when planning STEM programs for their teachers.

Time—Participants must have ample time to learn, plan, and implement effectively. Their training should be job-embedded and priority in the professional development workshop should be given to learning to use and design lessons with the equipment they will be using. The learning experience should be continuous, with a structure in place for teachers to learn in groups and over time. One 7-hour day of traditional PD is insufficient for true transformative professional STEM learning. The workshop may also be designed to span multiple days, whether scattered across the school year or as 1 intensive week. The more protected time teachers have to learn collaboratively, the more deeply they will absorb the learning experience.

Efficacy—Building teachers' self-efficacy in STEM will positively impact their ability to design STEM learning for their students. Professional development designers and technology leaders should be intentional about including activities that will build and assess teachers' self-efficacy in their STEM equipment as well as their self-confidence in being able to manage a STEM-focused classroom before the conclusion of the workshop. Teachers should be challenged but also set up to experience success and positive experiences during the training. STEM PD pedagogy should include explicit (I do, we do, you do) modeling on how this type of teaching and learning work in real classrooms with real students. This could even include school site visits so that PD leaders can model use of the STEM equipment in an authentic environment.

There should be movement and interaction throughout the workshop, with hands-on learning experiences that are relevant to the subjects and standards the teachers currently teach. STEM PD should also be collaborative in nature. Teachers from the math, science, and technology disciplines should be grouped and given authentic challenges to complete—those related to their students' STEM learning as well as their own methodology for STEM teaching. Participants' STEM efficacy should also be nurtured through the modeling of cross-content collaboration from district leadership. When science and math teachers observe their science and math district supervisors collaboratively designing and implementing a lesson with STEM, their confidence in replicating that process will be cultivated.

Equipment—The selection of equipment for STEM programs can have a significant impact on the program's effectiveness. Faulty equipment or that which is disconnected from their content area frustrates teachers and students alike. When possible, professional development leaders should carefully research and beta-test equipment with students and practitioners before making mass purchases. They should include within the professional development workshop a session on managing a classroom using the various pieces of equipment—from whole group to stations to charging and storage solutions for teachers. The more teachers can learn about using and managing the equipment, the more comfortable they will be.

Limitations

The data were a limitation to this study. Because they were historical data, the researcher had no control over when and how the surveys were distributed. There was an imbalance in teacher responses to the T-STEM pre- and post-surveys, with 20 responses to the T-STEM pre-survey and 12 responses to the T-STEM post-survey. There were also only seven responses to the Teacher Follow-Up Survey. This could have been due to the timing of the survey administration in May. The 2017-2018 district calendar indicated that approximately the same time the surveys were sent out, grades were due. Classroom end-of-year inventories were also being conducted. There were many other end-of-year activities and deadlines that may have taken precedence over the STEM surveys. Teachers may not have had the time to complete the follow-up surveys as they did in the protected time during the February workshop when they completed the T-STEM Pre. Although all seven schools and all three teacher types participated in the program follow-up survey, no school had all three teacher types respond. There was inequity in representation because all three teacher types were not represented within each school.

Both quantity and quality of responses were an issue. Some of the teachers' responses to the program follow-up surveys were simple "yes" or "no" in response to "How did you . . ." questions. These questions would have been better communicated and clarified in interviews rather than a form-based survey. The timing of the student surveys (spring fever, end of the year, etc.) and/or the impulsivity of adolescents may have caused students to rush through their responses rather than really thinking about them. The method of survey administration with students was also a limitation. A more accurate picture of the students' growth in STEM confidence and attitudes could have been addressed if the survey administration was consistent across schools and if the data were coded to match participants' pre and post levels of STEM confidence and attitudes.

Conclusion

A growth in STEM self-efficacy was found for the teachers in this study. This affirms that effective professional growth includes practical use of the resources as found in Annetta et al. (2012). The keys to successful STEM professional development programs that were discovered included the importance of emphasizing Time, Efficacy, and Equipment, which affirms studies by Annetta et al. (2012), Bates and Morgan (2018), and Rosenzweig and Wigfield (2016) that STEM professional development is unique and demands distinctive effort to move teachers along in their STEM confidence and self-efficacy levels.

A significant difference in STEM self-efficacy was found across teacher types. This agrees with Parsons et al. (2016) that self-efficacy is built through knowledge of the subject. There was no significant relationship found between teachers' preparation and self-efficacy in STEM and students' confidence levels in STEM, which contradicts research studies that found a significant relationship between teachers' self-efficacy in STEM and the STEM confidence of their students (Nadelson et al., 2013; Satchwell & Loepp, 2002; Shoffner et al., 2015). This is an indication of the need for further study on the relationship between these two factors in this school district.

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CHAPTER III

STUDENT CONFIDENCE IN AND ATTITUDES TOWARD STEM: WHY THEY MATTER

Because both immediate and distant future economic success depend on an ability to innovate and collaborate in the areas of science, technology, engineering, and math (STEM), the return on investment of STEM education is strong. Workers in STEM careers earn more than the national average (Fayer et al., 2017), and earn at least 10% more than workers with similar education levels (Emeagwali, 2015). Additionally, while many STEM occupations will require a college degree, some do not, which increases both the potential rate of workforce entry and earning power of workers in this area (Emeagwali, 2015). Business leaders and instructional leaders view STEM education as a priority because a skills gap in science, technology, engineering, and math has been identified, leaving a projected shortfall of 5 million workers for STEM occupations by 2020 (Goodwin & Hein, 2016). The ultimate goal of STEM learning is to produce skilled workers who can contribute to the fields on which our future success as a nation will rely so heavily (Emeagwali, 2015; Garza Mitchell & Sawyer, 2017; Hoeg & Bencze, 2017a, 2017b).

The benefits to students provided by STEM learning are clear. By participating in STEM education, students will be more interested in and better equipped to select STEM careers when they become financial contributors to society. There are numerous other benefits to STEM learning as well (Deering et al., 2016). STEM learning by nature shows students the power of cross-curricular and comprehensive connections (Deering et al., 2016). Math as a standalone subject is one thing, but math instruction in connection to science, technology, and engineering is another and better experience entirely. STEM learning is set apart from traditional instructional methods in its reliance on immediate application. STEM learning provides students with the ability to immediately apply what they are learning. The “meta-discipline” of STEM (Vasquez, 2015) is growing in popularity not only because of its benefits to the economy, but also because of its immediate positive impact on more effective student learning (Vasquez, 2015; Yager, 2015).

One distinct fallacy of the concept of STEM education revealed by the literature is that STEM learning should only be for students who already demonstrate academic strengths in the areas of science, technology, engineering, and mathematics (Hall, 2015). On the contrary, STEM learning is beneficial to all students and in many cases especially those who do not demonstrate an aptitude for STEM early in life. STEM programs provide students with opportunities to experience traditional content in a new and interconnected way. STEM learning provides students with the chance to investigate and develop the 21st century learning skills of collaboration, creativity, and problem-solving and to learn them in an authentic way (Yager, 2015).

Purpose of the Study

The purpose of this study was to investigate how different groups of students’ confidence in and attitudes toward STEM compare before and after participating in a specific STEM program, and whether a difference exists based on school in students’ confidence in and attitudes toward STEM subjects and careers after participating in a STEM program.

Research Questions

The research questions for this study are:

1. Research Question 1: How do different groups of students' confidence in and attitudes toward STEM compare before and after participating in specific STEM activities?

   Null Hypothesis: There will be no difference in groups of students' confidence in and attitudes toward STEM.

2. Research Question 2: Will there be a difference based on school in students' confidence in and attitudes toward STEM subjects and careers after participating in a STEM program?

   Null Hypothesis 1: There will be no difference based on school in confidence in and attitudes toward STEM subjects and careers after participating in a STEM program.

Theoretical Framework

This article is framed in the theory of situated learning cognition. Situated learning cognition establishes the connection between true knowledge and use within context (Brown et al., 1989). Genuine knowledge is constructed through investigative learning, especially when acquired and tested within a community of practice (Lave & Wenger, 1991; Riveros et al., 2012). The STEM program investigated in this study includes students' active learning through use of Sphero robots, Little Bits circuitry kits, Lenovo Android tablets, and Cubelets robotic/circuitry sets. True knowledge of STEM and positive changes in STEM confidence and attitudes can come from true and contextual experiences with STEM in the formative adolescent years. This study explored the connection between students' active use of Sphero, Little Bits, Lenovo Android tablets, and Cubelets with comparisons by school and before/after groups in their confidence in and attitudes toward STEM.

Overview of the Literature

Adolescence as a Target age Group for STEM

The theoretical framework of situated learning cognition posits that the acquisition of knowledge cannot be separated from the practice of that knowledge (Brown et al., 1989). This is especially relevant to STEM learning because it exists only when there is immediate application of the skills and content knowledge students are actively learning (Vasquez, 2015). Additionally, this is specifically significant to the adolescent age group because of the state of the brain during these formative years. Cognitive processing and behavior are strongly related in adolescence (Bates, 2014).

During these formative years, adolescents are learning more information at a greater rate of intake than they ever will again in their lifetime. The physical changes of their brain chemistry, accelerated rate of synapses, and myelination mean that their brains are extremely active (Steinberg, 2012). They are primed to take in voluminous amounts of information at a rapid rate (Griffin, 2018; Steinberg, 2012). In addition, there is a spike in the increase of dopamine activity in adolescence, which indicates that students this age seek and respond more strongly to rewarding experiences than at any other time in life (Steinberg, 2011). Studies indicated that a result of this increased sensitivity to dopamine creates a remarkable level of response to risks and rewards in early adolescence, and also that it is significantly heightened when they are with their groups (Bates, 2014; Steinberg, 2012). This indicates that students of this age are primed to respond positively to challenges and learning activities in collaborative groups, which is a key feature of STEM learning (Rosenzweig & Wigfield, 2016). Emeagwali (2016) pointed out that STEM learning begins to decline in middle school, which is another indication of the relevance of targeting adolescents.

A primary focus for adolescents is the discovery of self, or development of their identity (Bates, 2014). Identity development contributes to confidence in an individual's abilities (Erikson, 1968). Significant and supportive relationships based on trust help adolescents learn to trust or have confidence in their own identity and abilities (Erikson, 1968; Ja & Jose, 2017; Jabeen, 2017; Watermeyer, Morton, & Collins, 2016).

Conversely, a lack of confidence will stifle the process of positive identity development in adolescents (Ja & Jose, 2017; Watermeyer et al., 2016). When students' confidence in their capacity to achieve in the areas of science, technology, engineering, and math is not nurtured, they avoid the pursuit of STEM learning and professions (Perez-Felkner, McDonald, Schneider, & Grogan, 2012; Watermeyer et al., 2016). To develop high confidence and positive attitudes toward STEM learning and professions, adolescents need exposure to teachers who also have high confidence in and positive attitudes toward STEM learning and professions (Sjaastad, 2013). Teachers should design learning experiences that enable adolescents to participate in and practice self-reflection on their STEM learning in order to build the students' confidence and interest in STEM fields (Jabeen, 2017; Watt et al., 2017).

Sjaastad (2013) conducted a study on the influence of "significant persons," especially teachers, on adolescents' attitudes toward STEM. The concept of attitude incorporates the individual's belief about himself/herself as well as his/her belief about the subject. In the study, Sjaastad developed a conceptual framework through which the mechanisms of teachers' influence on students' attitudes toward STEM learning and professions could be measured. The teachers' encouragement, efforts to inform students of STEM career prospects, exposure to positive scientific experts and role models, and modeling excitement and passion in their instruction were found to be positive contributing factors influencing students' attitudes toward STEM education and careers (Sjaastad, 2013).

The rapid development of the adolescent brain during this phase of life indicates a particularly vulnerable period of growth and development. Students' experiences in adolescence—whether negative or positive—will impact their thinking and perceptions for life (Bates, 2014; Rice et al., 2013). Positive and rewarding experiences with STEM in early adolescence sets the stage for a lifetime of positive experiences with STEM (Bates, 2014). Considering the formative nature of the adolescent years, it is up to educators and adults in society to provide these children with the best experiences that will shape their future thinking (Sjaastad, 2013). Because we know they are so moldable, we can influence their future by influencing their experiences today (Bates, 2014; Sjaastad, 2013).

Methods

The purpose of this study was to explore the success of a STEM program with adolescents in a public school district. The researcher was interested in how the program influenced students' confidence in and attitudes toward STEM.

The STEM program was implemented in a public school district in the southern United States over a period of 4 months. The STEM program was the result of a grant won by the school system to promote STEM learning in 6th grade students. The school district's purpose in applying for the grant was the need for STEM education for students in general as well as the specific demand for an emphasis on the formative 6th grade year of school. Research studies signifying a growing fissure of both interest and performance between races and gender in STEM areas also inspired the grant proposal (Muller et al., 2001). The district leadership team authoring the grant included a supervisor of technology, technology program specialist, and district technology coaches. The grant application included STEM equipment that, at the time, was widely used in K-12 education. The specific pieces of equipment included in the grant were Spheros robots, Little Bits, Lenovo tablets, and Cubelets. Teachers were not involved in selecting the equipment.

Once the grant was conferred, the school system procured STEM equipment kits and disseminated them to 6th grade science, technology, and math teachers. The STEM kits included the Spheros, Little Bits, Lenovo Android tablets, and Cubelets that were a part of the grant application for the STEM program. Spheros are palm-sized robotic spheres controlled with a linked app on a smartphone or tablet. Students can use drag and drop Blockly coding to create programs with a sequence of movements the Sphero performs once the code is launched. Students use trial and error to determine angles, distances, and behaviors in order to code the Sphero robot to accomplish specific goals like navigating a maze or to successfully move around obstacles without stopping. Little Bits are circuitry sets with which students can investigate a variety of combinations to create devices such as light sensors, operational fans, instruments, signal regulators, and sound indicators. The Cubelets are considered a flexible and segmented robotics set. Each cube is built to function with a certain sense (power, sight/camera, light, movement, etc.). Through investigation and by shifting the order and design of their cubed robots, students can use the Cubelets to develop their own understanding of how robots and artificial intelligence function. Each school's STEM kit was comprised of Spheros, Cubelets, and Little Bits as well as a Lenovo Android tablet intended to run the Spheros devices.

The equipment was an important piece of the STEM program, but the other portion was the implementation plan and support from the district for teachers. The 6th grade math, technology, and science teachers from each school were provided a substitute and invited to the central office for an explanation of the program. Within the professional development day, the school district's leadership informed teachers of the awarded grant and communicated the research that indicates the need for an increasing emphasis on STEM learning in 6th grade. By rotating subject-specific groups of teachers through stations stocked with the same equipment in their kits, the school district also provided teachers with hands-on opportunities to experiment and become confident in the equipment in their kits.

The teachers were added to a dedicated Google Classroom space and Team Drive as collective reference sources for them to use in searching and adding ideas and lessons relevant to their STEM efforts. Shortly after the teacher professional development workshop, the district sent out the *Student Attitudes Toward STEM Survey—Middle and High School Students* (S-STEM Pre) for teachers to post for their 6th grade students. These were administered through the technology courses mid-February. The same *Student Attitudes Toward STEM Survey—Middle and High School Students* (S-STEM Post) surveys were sent out again in May 2018 and through the same technology courses.

The theory of situated learning cognition indicates that authentic learning cannot be separated from its application (Brown et al., 1989). This framework provides a foundational function in the data collection and analysis process, because any changes in students' confidence in and attitudes toward of STEM before and after the program is implemented can only occur, and therefore, can only be measured if the students truly experience each portion of the program.

Setting

The setting for this study was a public school district which serves approximately 21,000 students in the southeastern United States (population information from district website). The study specifically focuses on Grade 6 in the seven middle schools in the district, referred to throughout as Schools A-G. Collectively the seven middle schools serve approximately 1,300 6th grade students. Though all schools serve grades 6-8, they vary demographically and socioeconomically. The differences in population, race, gender, and free/reduced lunch status are seen in Table 3.1. Free/Reduced lunch status is an indication of poverty level in the community served by a school. Information for Table 3.1 was sourced from the district as well as schools' and community websites.

Table 3.1

Comparison of School Demographics

School	Population	Race	Gender	Free/Reduced Lunch
School A	328	White: 51% Black: 31% Hispanic/Latinx: 16.5% Biracial/Other: 1.5%	Male: 51% Female: 49%	64%
School B	432	White: 81.7% Black: 12% Hispanic/Latinx: 4.9% Biracial/Other: 1.4%	Male: 49% Female: 51%	56%
School C	1007	White: 86.7% Black: 7.1% Hispanic/Latinx: 3.7% Biracial/Other: 2.5%	Male: 51% Female: 49%	16%
School D	1109	White: 75.3% Black: 11% Hispanic/Latinx: 6.8% Biracial/Other: 6.9%	Male: 52% Female: 48%	15%
School E	457	White: 72.6% Black: 23.6% Hispanic/Latinx: 1.5% Biracial/Other: 2.3%	Male: 52% Female: 48%	63%
School F	668	White: 56% Black: 33.2% Hispanic/Latinx: 7.8% Biracial/Other: 3%	Male: 50% Female: 50%	45%
School G	964	White: 78.8% Black: 12% Hispanic/Latinx: 4.1% Biracial/Other: 5.1%	Male: 50% Female: 50%	18%

Participants

This study was an analysis of historical data that were collected from 6th grade students, existing as a result of surveys administered as part of the evaluation of a STEM program grant awarded to the school district. The surveys were administered through the students' technology courses mid-February and resulted in 286 responses. The same surveys were administered again in May 2018 and through the technology courses and resulted in 470 responses. The two groups of students were different students because in this district the 6th grade students rotate through different electives each 9-week period, therefore, the students surveyed in February were different from those surveyed in May. Participation varied across schools.

Instrumentation

The *Student Attitudes toward STEM Survey—Middle and High School Students (*S-STEM) was the instrument being used for this study (see Appendix C). The survey is derived from the North Carolina State University's Friday Institute and is reported to be a valid and reliable survey with "demonstrated evidence of configural, metric, and scalar invariance across grade levels, races/ethnicities, and genders" (Unfried, Faber, Stanhope, & Wiebe, 2015, p. 15). The S-STEM survey was selected by the district because it was already developed, had been used successfully with other STEM programs, and was free. The Friday Institute granted the school district permission to use and edit the survey instrument.

The district elected to reduce the total number of questions for students from 56 items on the S-STEM to 25. This impacts the validity and reliability of the survey instrument, but the school district believed it to be in the best interest of their students. The district's purpose in reducing the survey items was to protect participants from survey fatigue and to ensure the greatest number of completed questionnaires. The Cronbach alpha test was used to gauge the internal consistency and reliability of the modified surveys.

Data Collection

Because the STEM program was grant-funded, the district needed to evaluate its effectiveness. The S-STEM Survey was used as a pre and post measure. The S-STEM was administered during the students' technology classes in February 2018 as a pre-survey and in May 2018 as a post-survey. However, the students taking the pre- and post-surveys were not the same students because in this district the 6th grade students rotate through different electives each 9-week period, therefore, the students surveyed in February were different than those surveyed in May. Participation varied across schools.

Data Analysis

The two groups of students' S-STEM surveys from before and after the STEM program were quantitatively analyzed using an ANOVA. The significance level was .05. Since the number of pre and post participants was so different and because the students in the technology courses were different in February and May, scores for the students could not be matched. The two groups were treated as two independent groups of students, not as a pre-post design.

Results

The sample size for the S-STEM pre-survey was 286. This sample represented 6th grade students in seven different middle schools within the district, though there were only responses from four of the seven schools. There was a variety of representation across the four schools, with School D having the lowest percentage at 0.7% and School B having the highest percentage at 46.5%. These can be seen in Table 3.2.

Table 3.2

S-STEM Pre-survey Participation by School

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	93	32.5	32.5	32.5
	B	133	46.5	46.5	79.0
	C	58	20.3	20.3	99.3
	D	2	.7	.7	100.0
	Total	286	100.0	100.0	

Of the 286 6th grade respondents, 133 (46.5%) were male and 144 (50.3%) were female. Nine (3.1%) students indicated that they preferred not to answer the gender question on the survey. For race, 196 (68.5%) were White, 35 (12.2%) were Black, 42 (14.7%) were Hispanic/Latinx, and 13 (4.5%) were considered Other. The "Other" category was collapsed to include Biracial, Native American, and Asian/Pacific Islander.

The overall sample size for the S-STEM post-survey was 470. This sample represented 6th grade students in seven different middle schools within the district. There was a variety of representation across the seven schools, with School F having the lowest percentage at 1.5% and School B having the highest percentage at 29.8%. These can be seen in Table 3.3.

Of the 470 6th grade respondents, 229 (48.7%) were male and 225 (47.9%) were female. Sixteen (3.4%) students indicated that they preferred not to answer the gender question on the survey. For race, 332 (71%) students were White, 53 (11%) were Black, 47 (10%) were Hispanic/Latinx, and 38 (8.1%) were considered Other. The "Other" category was collapsed to include Biracial, Native American, and Asian/Pacific Islander.

Table 3.3

S-STEM Post-survey Participation by School

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	93	19.8	19.8	19.8
	B	140	29.8	29.8	49.6
	C	108	23.0	23.0	72.6
	D	24	5.1	5.1	77.7
	E	59	12.6	12.6	90.2
	F	7	1.5	1.5	91.7
	G	39	8.3	8.3	100.0
	Total	470	100.0	100.0	

The original S-STEM survey instrument from the Friday Institute contained 56 items. The district elected to reduce the number of items to protect students from survey fatigue. The modified S-STEM survey contained 25 items. Items 2 and 8 were reverse coded due to negative wording. The S-STEM pre-survey had a reliability coefficient using Cronbach's alpha of .817 and S-STEM post-survey had .821. This indicated strong internal validity and reliability for the modified instrument.

Research Question 1

The first research question asked how different groups of students' confidence in and attitudes toward STEM compared before and after participating in the STEM program. The S-STEM was used as a pre- and post-survey (see Appendix C). The S-STEM was a survey measuring STEM confidence and attitudes in students. It was made up of 25 questions, all of which were answered using a 5-point Likert-type scale. Response options for the S-STEM were 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. Two of these 25 items were reverse coded due to negative wording.

The pre and post groups of students were considered independent samples because they were different groups of students, meeting the assumption for a one-way ANOVA. The assumption of homogeneity of variance was also tested and met for the ANOVA with an insignificant Levene statistic of .780. The ANOVA was used to compare means between the group of students surveyed before the STEM program and the group of students surveyed after the STEM program. Since $F = 4.749$ and $p = .030$, the null hypothesis was rejected. There was a significant difference in groups of students' confidence in and attitudes toward STEM after participating in a STEM program. The pre-survey average was 81.38, while the post-survey average was 83.25 as shown in Table 3.4. These analyses indicated that the students had a higher level of confidence in and attitudes toward STEM after participating in the STEM program. Means and standard deviations of both groups are also shown in Table 3.4.

Table 3.4

Comparison of Student Group Means

					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Students PRE	286	81.38	11.404	.674	80.05	82.71	36	109
Students POST	470	83.25	11.465	.529	82.21	84.29	28	118
Total	756	82.54	11.470	.417	81.72	83.36	28	118

Research Question 2

The second research question asked whether a difference existed in STEM confidence and attitudes across the different middle schools in the district. To investigate this, the S-STEM post survey (see Appendix C) was used. The S-STEM was a survey measuring STEM confidence and attitudes in students. It was made up of 25 questions, all of which were answered using a 5-point Likert-type scale. Response options for the S-STEM were 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. Two of these 25 items were reverse coded due to negative wording.

The different groups of students in each middle school were independent samples, which met the assumption for a one-way ANOVA. The assumption of homogeneity of variance was also tested and met for the ANOVA with an insignificant Levene statistic of .363. The ANOVA was used to compare means between the group of students surveyed before the STEM program and the group of students surveyed after the STEM program.

The seven middle schools were coded into School A, B, etc. While a difference of the means is present (see Table 3.5), $p = .450$, so the null hypothesis was not rejected. There is no difference in confidence in and attitudes toward STEM in the different schools across the district. This could indicate that the STEM program was equally implemented across the 6th grade student population in this school district.

Limitations

The data are a limitation for this study. A perfect balance between pre- and post-survey group responses is optimal, but the historical data contained a significant imbalance in student responses. Because the students surveyed in February were different from those surveyed in May, and due to the deidentified nature of the historical data, it was not possible to match individual students' responses to the pre- and post-surveys, which would have been a best case scenario for the most accurate evaluation of the STEM program's impact. Participation varied across schools.

Table 3.5

Comparison of Means Across Schools

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
A	93	83.49	10.668	1.106	81.30	85.69	36	104
B	140	81.96	11.903	1.006	79.97	83.95	35	108
C	108	83.42	11.412	1.098	81.24	85.59	52	113
D	24	81.50	15.424	3.148	74.99	88.01	28	101
E	59	84.19	9.429	1.228	81.73	86.64	55	103
F	7	83.86	13.069	4.940	71.77	95.94	62	97
G	39	86.41	11.623	1.861	82.64	90.18	63	118
Total	470	83.25	11.465	.529	82.21	84.29	28	118

Conclusions

There was a significant growth found in students' STEM confidence, which affirms Sjaastad's (2013) results, which showed that teachers can influence their adolescent students' attitudes toward STEM learning and careers. Additionally, no difference was found in students' confidence in the seven schools across the district, which affirms findings from Hall (2015), indicating that STEM learning may be appropriate for all students.

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CHAPTER IV

FINDING THE MISSING PIECES: NURTURING FEMALE AND MINORITY STUDENTS IN STEM

The Problem of Perception

Although many K-12 organizations and postsecondary schools have made efforts to increase the number of females represented in the areas of science, technology, engineering, and math (STEM) occupations, women remain underrepresented in these fields (Bieri Buschor et al., 2014; Else-Quest, Mineo, & Higgins, 2013; Osei-Kofi & Torres, 2015; Saw, Chang, & Chan, 2018). In 2013, a mere 8% of STEM occupations were held by individuals who were both female and an ethnic or racial minority (Else-Quest et al., 2013). The unrelenting, downward trend of racial underrepresentation in STEM doctoral programs is, for some, an indicator of future economic disaster in the United States (Bancroft, 2018). Research indicated many reasons for this, including poor self-efficacy in the STEM disciplines and gender stereotypes resulting from "chronic oppressive barriers" (Bancroft, 2018, p. 1321; Brown, Ernst, Clark, DeLuca, & Kelly, 2017; Rice et al., 2013; Watt et al., 2017).

There is no indication that one gender is genetically inclined toward or against STEM occupations (Blažev, Karabegović, Burušić, & Selimbegović, 2017; Boston & Cimpian, 2018; Brown et al, 2017; Perez-Felkner et al., 2012). Learners' confidence in science has demonstrated a stronger indication of future academic achievement than other factors such as gender or background (Annetta et al., 2012). Additionally, the literature demonstrates that although there is equality in STEM ability among all racial groups, there remains low perceptions of STEM careers by minorities and females (Else-Quest et al., 2017). Racial stereotypes in the STEM subjects toward African American and Latino students negatively affect these minority students' interests in STEM fields (Else-Quest et al., 2017). Females and males are fairly and equally equipped by nature to participate in STEM fields, but males exhibit higher self-efficacy in STEM subjects, which is what can have the highest impact in career selection (Brown et al., 2017; Perez-Felkner et al., 2012). The literature also indicates that a significantly influential factor in females' pursuit of mathematics and science-oriented college coursework is an interest in science early in life (Bieri Buschor et al., 2014).

Purpose of the Study

The purpose of this study is to investigate whether there is a difference based on race or gender in students' confidence in and attitude toward STEM subjects and careers after participating in a STEM program.

Research Questions and Hypotheses

The research questions were

Research Question 1: Will there be a difference based on gender in confidence in and attitudes toward STEM subjects and careers after participating in a STEM program?

> Null Hypothesis 1: There will be no difference based on gender in confidence in and attitudes toward STEM subjects and careers after participating in a STEM program.

Research Question 2: Will there be a difference based on race in confidence in and attitudes toward STEM subjects and careers after participating in a STEM program?

> Null Hypothesis 2: There will be no difference based on race in confidence in and attitudes toward STEM subjects and careers after participating in a STEM program.

Research Question 3: Will females' confidence in and attitudes toward STEM subjects and careers be higher after participating in a STEM program?

Null Hypothesis 3: There will be no difference in females' confidence in and attitudes toward STEM subjects and careers after participating in a STEM program.

Research Question 4: Will minorities' confidence in and attitudes toward STEM subjects and careers be higher after participating in a STEM program?

Null Hypothesis 4: There will be no difference in minorities' confidence in and attitudes toward STEM subjects and careers after participating in a STEM program.

Theoretical Framework

The theoretical framework for this study was the theory of situated learning cognition. Situated learning cognition establishes the connection between genuine knowledge and use within context (Brown et al., 1989). True knowledge is created through experiential learning (Brown et al., 1989). The STEM program investigated in this study includes female and minority students' active learning through use of Sphero robots, Little Bits circuitry kits, Lenovo Android tablets, and Cubelets robotic/circuitry sets. True knowledge of STEM and positive changes in STEM perceptions can come from true and contextual experiences with STEM in the formative adolescent years. This study will explore the connection between female and minority students' active use of Sphero, Little Bits, Lenovo Android tablets, and Cubelets and changes in their confidence in and attitudes toward STEM.

Overview of the Literature

To understand the roots of the representation issue for females and minorities in STEM fields, an examination is needed of gender and race as they relate to culture. In this study, minority populations specifically refer to Black and Hispanic/Latinx people. Critical race theory

(CRT) is a study of the relationship between race and/or gender and power (Delgado & Stefancic, 2017). CRT was first developed among attorneys and other experts of the law as a social and legal construct but has since extended into other branches of knowledge (Delgado & Stefancic, 2017). The field of education research has grown significantly in recent years to include studies on the significance of CRT in the routine instructional business of K-12 schools (Bancroft, 2018; Delgado & Stefancic, 2017; McGee & Bentley, 2017; McGee & Pearman, 2014; McGee & Stovall, 2015; Morettini, 2017; Morton & Parsons, 2018; Ridgeway & McGee, 2018; Ridgeway & Yerrick, 2018). Disciplinary issues, standardized test results, and revisionist curricula are all being investigated through the CRT lens (Delgado & Stefancic, 2017). The concept of microaggressions or small negative occurrences with racism or sexism that could be verbal, nonverbal, or environmental typically undetected by members of the majority race/gender is also a part of the critical race theory (Delgado & Stefancic, 2017; Grossman & Porche, 2014; Morton & Parsons, 2018). An example of a racial microaggression could be a Black student raising her hand multiple times in class and never being called on by her White teacher, while an example of a sexist microaggression could be a male teacher appointing only male students as group project leaders.

Because CRT includes consideration of the microaggressions minorities and females experience in the details of their everyday lives, it also offers an explanation for how this impacts these individuals' mental health, self-concepts, and aspirations for the future (Delgado & Stefancic, 2017; Grossman & Porche, 2014; McGee & Bentley, 2017; McGee & Stovall, 2015; Ridgeway & Yerrick, 2018). When minority and female students have consistently negative experiences with STEM learning due to racial or sexist microaggressions or stereotyping, they are discouraged from STEM education (Grossman & Porche, 2014; Leath & Chavous, 2018; Morton & Parsons, 2018; Ridgeway & McGee, 2018).

Although both racial minorities and female students experience barriers to successful creation of a positive STEM self-concept, the difficulties each face are distinctive (Grossman & Porche, 2014). Black and Hispanic/Latinx students are stereotyped in the classroom and society as having low capacity and aptitude in science and math (Leath & Chavous, 2018; Tatum, 1997). They receive discriminatory "microinsults" questioning their intelligence (Grossman & Porche, 2014, p. 701). Because STEM culture is historically White, assimilation places pressure on Black individuals to sacrifice their self-identified culture; this adds a cognitive stressor many find too high a price (Martin, 2016; McGee & Stovall, 2015). "Chronic exposure to these negative micromessages is emotional and cognitive stress that depletes individual resources for STEM success and leads to attrition" (Grossman & Porche, 2014, p. 702).

In regard to gender, there are more girls and women capable of success in STEM occupations than are pursuing them; as with race, the representation problem falls with motivation and interest rather than ability (Stoet & Geary, 2018). Many parents and teachers perpetuate gender stereotypes and societal roles by indicating that STEM occupations are too masculine for girls and that girls are not as good at math, science, technology, and engineering as boys (Bottia, Stearns, Mickelson, Moller, & Valentino, 2015; Heybach & Pickup, 2017; Master & Meltzoff, 2016). As a result, females lack confidence in math and science, even when their abilities are equal to their male counterparts (Barth, Kim, Eno, & Guadagno, 2018). This "microinvalidation" erroneously assumes that all girls have the same academic strengths, interests, and abilities (Grossman & Porche, 2014). Additionally, STEM fields are seen as stressful, competitive, and inappropriate for women (Wang, Young Lee, & Prevost, 2017). Many women view STEM careers as incompatible with raising a family and as isolated rather than purposed to help others (Heybach & Pickup, 2017). Given the ubiquitous persona of a scientist as a White, nerdy male (Blažev et al., 2017) coupled with the lack of female role models in STEM, many girls are discouraged from the field (Master & Meltzoff, 2016). Further detractors are that girls experience more sexual harassment at school (Andrus, Jacobs, & Kurloff, 2018) and receive more comments from adults about their appearance rather than their academic ability (Andrus et al., 2018).

In a study on gender stereotypes in STEM, Blažev et al. (2017) found that gender stereotypes toward STEM influencing career choices and future academic aspirations form as early as age 10. Parents and teachers alike convey attitudes that the mathematical abilities of girls are inferior to those of boys (Gladstone, Turci, Häfner, Kneißler, & Muenks, 2018). Furthermore, the middle school years are when many girls begin to diverge from interest and participation in STEM learning (Barth et al., 2018; Emeagwali, 2016; Kim, Sinatra, & Seyrian, 2018).

Differences in gender representation in STEM could be caused by barriers such as scarcity of female role models and mentors (Heybach & Pickup, 2017). Marketing STEM materials and curriculum as feminine—or pink-washing—can make a difference in younger girls' perceptions of STEM play, but repackaging STEM toys in pastel colors merely perpetuates the stereotype that girls must adapt to the social and historical boundaries associated with gender and science/engineering (Heybach & Pickup, 2017). Pink-washing STEM materials is a flimsy fix without authentic foundational shifts in STEM education and culture (Heybach & Pickup, 2017).

The elimination of gender-based contributions to STEM leadership, learning, and advocacy is not the solution; embracing the contributions girls and women can make *because of* their life experiences and identity as females is what is necessary for STEM's cultural advancement (Heybach & Pickup, 2017). Kim et al. (2018) likened this concept to the radical improvements made in women's healthcare once more women became physicians. Rather than girls and women adapting to fit into the traditionally male STEM culture, the world of STEM should be reinvented to embrace girls and women and the unique strengths and perspectives they bring as females (Heybach & Pickup, 2017). This can occur when more women pursue leadership roles within STEM culture (Lewis, 2018).

Students who are members of two or more of the identified underrepresented populations of race, gender, and socioeconomic (SES) status—such as Black females—are positioned to be most vulnerable, and, therefore, need the most support and encouragement in STEM learning (Morton & Parsons, 2018; Saw et al., 2018). The combination of multiple marginalized categories—such as with racism and sexism—exacerbates their vulnerability in society (Tatum, 1997). Leading intersectional lives, Black females have a greater chance of facing institutional racism than their male counterparts (Carter & Reynolds, 2011; Morton & Parsons, 2018). A study by Young, Young, and Capraro (2017) indicated that STEM diversion can begin in the transition to middle school when mathematics is abruptly perceived as a male dominion. This, coupled with pervasively low recognition of Black students' academic abilities, can discourage Black females from believing the math and science domains are for them (Young et al., 2017). Black girls are discouraged from taking rigorous math and science courses in high school, and there are insufficient STEM classes offered in the low SES schools many attend (McGee & Bentley, 2017). A study by Leath and Chavous (2018) on Black women's campus experiences in STEM majors indicated that, in comparison to other women, Black women reported significantly more tension, distrust, and racial interiorization in the classroom. Low academic satisfaction due to these factors can cause Black females to discontinue pursuit of STEM professions (Leath & Chavous, 2018). An additional study by Morton and Parsons (2018) on STEM identity conceptualization in Black women found that traditional STEM education propagates a culture that is primarily Euro/Anglo/White, middle class, and male; this creates persistent marginalization for those who are navigating multiple identities within their underrepresented groups. It is essential that K-12 and higher education instructors understand this and are committed to supporting their students' needs (McGee & Bentley, 2017; Morton & Parsons, 2018).

Conversely, just as negative experiences can deter students from pursuing STEM fields, positive experiences with intentional and culturally sensitive teachers and mentors can certainly encourage interest in STEM education and professions (Morettini, 2017; Ridgeway & Yerrick, 2018). When encouraged in math and science success by role models within their school such as principals, coaches, and counselors, students of any race and gender are positioned for accomplishment (McGee & Pearman, 2014).

Teachers hold positions of power (Ridgeway & Yerrick, 2018). Their treatment of and interactions with students lay the foundation for what will be either a positive or negative teaching and learning relationship as well as the students' perceptions of the subjects being taught (Ridgeway & Yerrick, 2018). STEM-focused schools or academies (Bullock, 2017) and single-sex schools (Park, Behrman, & Choi, 2018) can cultivate minority and female students' interests in STEM education, but widespread access to STEM-academies and gender-sorted schools is unrealistic. Teachers in the areas of STEM who make an effort to build relationships with all their students based on support, respect, trust, empathy, and acceptance can positively nurture students' pervasive interests in STEM fields (Bancroft, 2018; Grossman & Porche, 2014).

Teachers can minimize microaggressions in the classroom through an awareness of the ways power, race, and gender impact the education process (Ridgeway & Yerrick, 2018). Serving as or securing role models for female students and STEM mentors from minority backgrounds can increase their confidence in and attitudes toward STEM learning (Grossman & Porche, 2014; Morettini, 2017). Forming communities of practice such as STEM clubs with girls can provide the personal connection needed to retain their interest in STEM fields (Boston & Cimpian, 2018). For STEM advocates and leaders, the culture of STEM should be reimagined to embrace the influence of a diverse community (Kim et al., 2018). One necessary area of change is to develop more communal and family-friendly practices within scientific culture (Clark, Fuesting, & Diekman, 2016; Wang & Degol, 2017). For STEM teachers, authentic change can be cultivated by intentionally disputing racial/gender stereotypes and including culturally relevant topics; drawing in the marginalized in STEM instruction will enhance *all* students' learning experiences (Heybach & Pickup, 2017; Morettini, 2017; Ridgeway & Yerrick, 2018).

Authentic Learning for All

The theoretical framework of situated learning cognition indicates that active, authentic learning provides students with experience (Brown et al., 1989). The active creation of experiences is the core of learning itself (Brown et al., 1989). Situated learning cognition also emphasizes authentic, experiential learning through collaborative interactions such as collective problem solving, taking on different roles, and working through mistakes and misunderstandings (Brown et al., 1989). STEM learning embodies all of these factors, and if implemented well, can provide all adolescents, including females and minority students, with positive experiences that will lead them to the participation of STEM subjects in their secondary and postsecondary schools and/or entry to STEM professions.

World-changing STEM Power

Marie Curie of radioactivity, Katherine Johnson of *Hidden Figures*, and Maria Goeppert-Mayer of the Super Bomb are a few famous scientists who have left a strong impact on the world (Emeagwali, 2016). They are among the few female and minority role models in STEM fields for students today, but a focus on these individuals can provide learners with the inspiration to pursue STEM learning and occupations in order to change the world (Bieri Buschor et al., 2014; Emeagwali, 2016). Martin (2016) explored the effects of cultural assimilation on students, and posited that when a student positively identifies with (or is represented in) the learning environment, they are comfortable and satisfied with the content. When students are forced to assimilate to an unfamiliar environment to which they have no connection, their comfort and satisfaction levels will be low (Martin, 2016). This indicates a need to ensure representation of female and minority STEM leaders in classrooms.

Females who do select careers in STEM areas demonstrate a “very strong expectation that they can make the world a better place” (Bieri Buschor et al., 2014, p. 168). When STEM education is positioned within the context of authentic, problem-based learning, the notion of becoming a problem-solver can take root in all students’ minds, especially that of females and minorities (Bieri Buschor et al., 2014).

Methods

The purpose of this study was to investigate whether differences exist among the genders and races in regard to confidence in and attitudes toward STEM. The STEM program, implemented in a large southeastern public school district over a period of 4 months, was the result of a grant awarded to the district to promote STEM learning in 6th grade students. The district pursued the grant because of the need for STEM education in general as well as the specific call for a focus on the impressionable 6th grade year. Research indicating a widening gap of both interest and performance between races and genders in STEM areas also played a motivating role in the submission of the grant application (Muller et al., 2001). The district representatives who collaboratively authored the grant were the technology supervisor, a technology program specialist, and district technology coaches. Their application included the Spheros robots, Lenovo tablets, Cubelets modular robots, and Little Bits circuitry kits.

Once awarded grant funding, the district purchased items and formed kits of STEM-focused equipment to be disseminated to 6th grade science, technology, and math teachers. Included in the kits were the Spheros, Little Bits, Lenovo Android tablets, and Cubelets that were written into the grant application. Spheros are round robotic balls that can be controlled remotely using a linked app on a smartphone or tablet. Students can use drag and drop Blockly coding to write programs made up of a series of actions the Sphero performs once the code is launched. They test and retest, working through angles, distances, and behaviors in order to program the Sphero robot to achieve certain goals such as navigating a maze or other challenges. Little Bits are sets of magnetic circuitry pieces with which students can experiment to create a variety of devices such as alarms, timers, musical instruments, signal regulators, fans, and buzzers. The Cubelets are considered a modular robotics set. Each cube in a set is designed with a certain sense (power, sight/camera, light, movement, etc.) and through experimentation students can use Cubelets to learn how robots function as they build them in a variety of ways. Each school's kit contained Spheros, Cubelets, and Little Bits as well as a Lenovo Android tablet with which to run the Spheros devices.

Shortly after a professional development session with the participating teachers, the district sent out the *Student Confidence in and Attitudes Toward STEM* (S-STEM Pre) surveys for teachers to administer to their 6th grade students. These were administered through the technology courses in February 2018. The same surveys (S-STEM Post) were sent out again in May 2018 and through the same technology courses with different students.

The theory of situated learning cognition indicates that authentic learning cannot be separated from its application (Brown et al., 1989). This theoretical framework provided a foundational function in the data collection and analysis process of the current study, because any changes in female and minority students' perceptions of STEM before and after the program is implemented can only occur and, therefore, can only be measured if the students truly experience each portion of the program. The research questions were addressed through quantitative analysis of S-STEM and S-STEM administered as a pre- and post-survey.

Setting

The setting for this study was a public school district which serves approximately 21,000 students in the southeastern United States (population information from district website). The study specifically focused on Grade 6 in the seven middle schools in the district, referred to throughout as Schools A-G. Collectively, the seven middle schools serve approximately 1,300 6th grade students. Though all schools serve grades 6-8, they vary demographically and socioeconomically. The differences in population, race, gender, and free/reduced lunch status are seen in Table 4.1. Free/Reduced lunch status is an indication of poverty level in the community served by a school. Information for Table 4.1 was sourced from the district as well as schools' and community websites.

Table 4.1

Comparison of School Demographics

School	Population	Race	Gender	Free/Reduced Lunch
School A	328	White: 51% Black: 31% Hispanic/Latinx: 16.5% Biracial/Other: 1.5%	Male: 51% Female: 49%	64%
School B	432	White: 81.7% Black: 12% Hispanic/Latinx: 4.9% Biracial/Other: 1.4%	Male: 49% Female: 51%	56%
School C	1007	White: 86.7% Black: 7.1% Hispanic/Latinx: 3.7% Biracial/Other: 2.5%	Male: 51% Female: 49%	16%
School D	1109	White: 75.3% Black: 11% Hispanic/Latinx: 6.8% Biracial/Other: 6.9%	Male: 52% Female: 48%	15%
School E	457	White: 72.6% Black: 23.6% Hispanic/Latinx: 1.5% Biracial/Other: 2.3%	Male: 52% Female: 48%	63%
School F	668	White: 56% Black: 33.2% Hispanic/Latinx: 7.8% Biracial/Other: 3%	Male: 50% Female: 50%	45%
School G	964	White: 78.8% Black: 12% Hispanic/Latinx: 4.1% Biracial/Other: 5.1%	Male: 50% Female: 50%	18%

Participants

The data for this study were historical data collected during the evaluation of a middle school STEM program in a public school district. All 6th graders in the school district were participants in the STEM program and given the opportunity to complete the S-STEM surveys. The surveys were administered through the technology courses mid-February and resulted in 286 responses. The same surveys were administered again in May 2018 through the same technology courses with a different group of students and resulted in 470 responses.

Instrumentation

The instrument for this study is the *Student Attitudes Toward STEM Survey – Middle and High School Students* (S-STEM). It was derived from the North Carolina State University's Friday Institute and was reported to be a valid and reliable survey with "demonstrated evidence of configural, metric, and scalar invariance across grade levels, races/ethnicities, and genders" (Unfried et al., 2015, p. 15). The S-STEM survey was selected by the district because it already existed, had been used successfully with other STEM programs, and was free. The Friday Institute granted the school district permission to use and edit the survey instrument.

The school district elected to modify the survey, so reliability was analyzed for this study using the Cronbach Alpha test. The total number of questions for students was reduced from 56 items to 25. The district's purpose in decreasing the survey items was to protect participants from survey fatigue and to ensure the greatest number of completed questionnaires.

Data Collection

Because the STEM program was grant-funded, the district needed to evaluate its effectiveness. The S-STEM was administered during the students' technology classes in February 2018 and again in May 2018. The 6th grade students in this district take four different electives throughout the year and rotate each 9-week grading period, so the students surveyed in February were not the same as those surveyed in May. Survey administration and participation varied among the seven middle schools in this district.

Data Analysis

The study research questions were analyzed quantitatively using ANOVA, Kruskal-Wallis and independent *t*-tests. The significance level was .05.

Results

The overall sample size for the S-STEM pre-survey was 286. This sample represented 6th grade students in seven different middle schools within the district, though there were only responses from four of the seven schools. There was a variety of representation across the four schools, with School D having the lowest percentage at 0.7% and School B having the highest percentage at 46.5% (see Table 4.2).

Table 4.2

S-STEM Pre-survey Participation by School

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	93	32.5	32.5	32.5
	B	133	46.5	46.5	79.0
	C	58	20.3	20.3	99.3
	D	2	.7	.7	100.0
	Total	286	100.0	100.0	

Of the 286 6th grade respondents, 133 (46.5%) were male and 144 (50.3%) were female. Nine (3.1%) students indicated that they preferred not to answer the gender question on the survey. Of the 286 participants, 195 (68.5%) were White, 35 (12.2%) were Black, 42 (14.7%) were Hispanic/Latinx, and 13 (4.5%) were considered Other. The “Other” category was collapsed to include Biracial, Native American, and Asian/Pacific Islander. The overall sample size for the S-STEM post-survey was 470. This sample represented 6th grade students in seven different middle schools within the district. There was a variety of representation across the seven schools, with School F having the lowest percentage at 1.5% and School B having the highest percentage at 29.8% (see Table 4.3). Comparatively, the demographics for teachers regarding gender and race are seen in Table 4.4.

Table 4.3

S-STEM Post-survey Participation by School

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	93	19.8	19.8	19.8
	B	140	29.8	29.8	49.6
	C	108	23.0	23.0	72.6
	D	24	5.1	5.1	77.7
	E	59	12.6	12.6	90.2
	F	7	1.5	1.5	91.7
	G	39	8.3	8.3	100.0
	Total	470	100.0	100.0	

Table 4.4

Comparison of Teacher Demographics

	Total	Percentage
Male	4	20%
Female	16	80%
White	18	90%
Minority	2	10%

Of the 470 6th grade respondents, 229 (48.7%) were male and 225 (47.9%) were female. Sixteen (3.4%) students indicated that they preferred not to answer the gender question on the survey. Of the 470 participants, 332 (71%) were White, 53 (11%) were Black, 47 (10%) were Hispanic/Latinx, and 38 (8.1%) were considered Other. The “Other” category was collapsed to include Biracial, Native American, and Asian/Pacific Islander. The original S-STEM survey instrument from the Friday Institute contained 56 items. The district elected to reduce the number of items to protect students from survey fatigue. The modified S-STEM survey contained 25 items. Items 2 and 8 were reverse coded due to negative wording. The S-STEM pre-survey had a reliability coefficient using Cronbach’s alpha of .817 and S-STEM post-survey had a reliability coefficient of .821. This indicated strong internal validity and reliability for the modified instrument.

Research Question 1

The first research question asked whether a difference existed in students’ STEM confidence and attitudes based on gender. To investigate this, the S-STEM (see Appendix C) was used as a post-survey. The S-STEM was a survey measuring STEM confidence and attitudes in students. It was made up of 25 questions, all of which were answered using a 5-point Likert-type scale. Response options for the S-STEM were 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. Two of these 25 items were reverse coded due to negative wording.

Differences in gender created independent samples, which met the assumption for a one-way ANOVA. However, the assumption of homogeneity of variance was violated for the ANOVA with a significant Levene statistic of .002. The Kruskal-Wallis tests was used as a non-parametric measure of comparing means between the male, female, and “prefer not to answer” groups of students surveyed after the STEM program.

A comparison of means indicated a slight difference in the means between males and females, with males scoring a mean of 83.87 on the S-STEM post survey and females scoring a mean of 82.62 on the S-STEM post survey. Students who indicated “prefer not to answer” scored a mean of 83.19 (see Table 4.5).

Table 4.5

Comparison of Means Across Genders

Gender	Mean	N	Std. Deviation
Male	83.87	229	13.061
Female	82.62	225	9.719
Prefer not to answer	83.19	16	9.711
Total	83.25	470	11.465

The Kruskal-Wallis non-parametric test indicated a significance level of .106. Because $p > .05$, the null hypothesis was not rejected for Research Question 1. There was no difference based on gender in confidence in and attitudes toward STEM subjects and careers after participating in a STEM program.

Research Question 2

The second research question asked whether a difference existed in students’ STEM confidence and attitudes based on race. To investigate this, the S-STEM (see Appendix C) was used as a post-survey. The S-STEM was a survey measuring STEM confidence and attitudes in students. It was made up of 25 questions, all of which were answered using a 5-point Likert-type scale. Response options for the S-STEM were 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. Two of these 25 items were reverse coded due to negative wording.

The groups were independent samples, which met the assumption for a one-way ANOVA. The assumption of homogeneity of variance was tested and met for the ANOVA with an insignificant Levene statistic of .233. The ANOVA was used to compare means between the male, female, and “prefer not to answer” groups of students surveyed after the STEM program. Means and standard deviations appear in Table 4.6. The ANOVA indicated a slight difference in the means between races, with Hispanic/Latinx students scoring a mean of 83.87 on the S-STEM post-survey and females scoring a mean of 82.62 on the S-STEM post-survey. This can be seen in Table 4.6.

Table 4.6

Comparison of Means Across Races

Race	Mean	N	Std. Deviation
White	83.11	332	11.334
Black	83.51	53	11.298
Hispanic or Latino	83.87	47	9.426
Other	83.34	38	15.041
Total	83.25	470	11.465

Since $p > .05$ (p = .975), the null hypothesis was not rejected for Research Question 2. There was no difference based on race in confidence in and attitudes toward STEM subjects and careers after participating in the STEM program.

Research Question 3

Research Question 3 asked whether female students’ STEM confidence and attitudes were higher after participating in the STEM program. To investigate this, the S-STEM post-survey (see Appendix C) was used. The S-STEM was a survey measuring STEM confidence and attitudes in students. It was made up of 25 questions, all of which were answered using a 5-point

Likert-type scale. Response options for the S-STEM were 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. Two of these 25 items were reverse coded due to negative wording.

The first group included respondents to the S-STEM pre-survey, which was administered before the STEM program began. This group contained 144 females. The second group included respondents to the S-STEM post-survey, which was administered in the final month of the school year and STEM program for these students. This group included 225 females. The first group scored a mean of 79.90 while the second group scored a mean of 82.62. These results are shown in Table 4.7.

The assumption of homogeneity of variance was violated for the independent *t*-test with a significant Levene statistic of .009 for these data. The Kruskal-Wallis test was used as a non-parametric measure of comparing means between the female groups of students surveyed before and after the STEM program.

Table 4.7

Comparison of Means Across Pre- and Post-survey Female Groups

	Group	N	Mean	Std. Deviation	Std. Error Mean
Females Total	FemalesPRE	144	79.90	9.832	.819
	FemalesPOST	225	82.62	9.719	.648

Since $p < .05$ ($p = .015$) the null hypothesis was rejected for Research Question 3. There was a significant difference in females' confidence in and attitudes toward STEM subjects and careers after participating in the STEM program.

Research Question 4

For Research Question 4, which asked whether minorities' confidence in and attitudes toward STEM subjects and careers were higher after participating in a STEM program, the S-STEM pre- and post-surveys (Appendix C) were analyzed. The S-STEM was a survey measuring STEM confidence and attitudes in students. It was made up of 25 questions, all of which were answered using a 5-point Likert-type scale. Response options for the S-STEM were 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. Two of these 25 items were reverse coded due to negative wording.

The groups were independent samples, which met the assumption for an independent *t*-test. The homogeneity of variance assumption was also met for the independent *t*-test with an insignificant Levene statistic of .270. The independent *t*-test was used to compare means of minority students' responses from those surveyed before and after the STEM program.

The first group included minority respondents to the S-STEM Pre, which was administered before the STEM program began. The second group included minority respondents to the S-STEM Post, which was administered in the final month of the school year and STEM program for these students. The sample did not reflect enough Black, Latinx, Asian, Biracial, or Native American responses to make individual subgroups, so all non-White responses were condensed to and analyzed as one collapsed category. The first group scored a mean of 82.87 while the second group scored a mean of 83.59. These results are shown in Table 4.8.

Table 4.8

Comparison of Means Across Pre- and Post-survey Minority Group

Group	N	Mean	Std. Deviation	Std. Error Mean
MinoritiesPRE	90	82.87	9.749	1.028

MinoritiesPOST	138	83.59	11.808	1.005

A slight gain in minorities' score averages appears on the S-STEM surveys after the STEM program. Analysis showed p = .631 (which can be seen in Table 4.8); however, because $p > \alpha$ (.05), the null hypothesis was not rejected for Research Question 3. There was no significant difference in minorities' confidence in and attitudes toward STEM subjects and careers after participating in the STEM program.

Discussion

The indication of no significant difference between males' and females' confidence in and attitudes toward STEM can be positive. This can mean that the girls feel just as confident in their ability to learn with STEM equipment and resources as their male counterparts. Likewise, the indication of no significant difference between races can also be positive. This can mean that minority students feel just as comfortable with and interested in STEM as their fellow students of the majority race. These results can signify equity across both genders and all races in confidence in and attitudes toward STEM across the district. The S-STEM post-survey of female students had higher confidence in and more positive attitudes toward STEM than were indicated by the S-STEM pre-survey group of female students. This could indicate positive gains as a result of exposure to the STEM equipment as well as from an emphasis on STEM from three of their content area teachers. This could also be a result of female students having female STEM mentors and role models in their science, math, and technology teachers. No change was indicated in the minority scores from comparison of the S-STEM pre- and post-groups. This could mean that there was no growth in minority students' confidence in and attitudes toward STEM, which could be the result of a lack of minority STEM mentors and role models in the science, math, and technology teachers (as indicated in Table 4.4). This could indicate a need for more minority STEM role models for students across the district.

Limitations

The data are a limitation for this study. It would have been most accurate to compare two matched sets of pre- and post-survey data across students, but due to the deidentified nature of the historical data as well as the students' rotation cycle through electives, this was not possible. A significant imbalance in the students' pre- and post-responses is also a limitation. Survey administration varied, with some teachers encouraging student participation more than others. Additionally, there is disproportion of minorities present in the population sample.

Conclusions

No differences in students' STEM confidence levels were found between genders, which affirms Brown et al. (2017), Perez-Faulkner et al. (2012), and Boston and Cimpian (2018) that neither gender is either more or less inclined to STEM learning or occupations. No differences in students' STEM confidence levels were found between races, which affirms Else-Quest et al. (2017) in that there is uniformity in STEM ability across all racial groups.

When analyzed more narrowly, the data revealed that females grew in their STEM confidence after the program, while minorities did not. The females' growth affirms the concept indicated by Sjaastad (2013) regarding what powerful influence teachers (in this district, female science and math teachers) can have over their adolescent students. The minorities' lack of growth supports several studies indicating how minority students can be discouraged from STEM learning if they lack minority STEM mentors. Those studies include Grossman and Porche (2014), Leath and Chavous (2018), Morton and Parsons (2018), and Ridgeway and

Yerrick (2018). This indicates a need for targeted emphasis in this district on minority role models for STEM education.

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CHAPTER V

DISCUSSION, LIMITATIONS, AND RECOMMENDATIONS

The purpose of the three studies in this dissertation was to investigate the impact of a STEM program on adolescents in a public school district. A need for focus on STEM education was established, as well as the need to evaluate the STEM program implemented by this public school district for 6th grade students and their science, math, and technology teachers. There were several ways the historical data provided by the school district were examined. There was a comparison of teachers' STEM efficacy and the STEM confidence of their students, and the STEM confidence and attitudes of different groups of students as well as matched groups of teachers who participated in the program were also explored. A comprehensive dissection was made of the students by both gender and race, and gains in the scale of females' and minorities' STEM confidence were sought. This section will include a discussion of major findings from each study in the dissertation, a connection to the theoretical framework, implications of the studies, and recommendations for future research.

Discussion of Major Findings

Each chapter within this dissertation encompassed its own unique findings, though all are interrelated through the theoretical framework of situated learning cognition. In Chapter II, this study found there was no relationship between teachers' efficacy and students' confidence in STEM, which disagrees with a variety of studies including Nadelson et al. (2013), Satchwell and Loepp (2002), and Shoffner et al. (2015). All of these studies indicated the significance between teacher efficacy and students' confidence in STEM, which indicates a need for further study of the connection between these two factors within this school district. There was a difference of STEM self-efficacy across the three teacher types, with technology teachers having the highest STEM confidence scores and math teachers having the lowest. This agrees with a study by Parsons et al. (2016) in that self-efficacy is built through knowledge of the subject, and technology teachers widely indicated a greater knowledge about STEM teaching and resources than teachers of other subject areas. This also agrees with Bates and Morgan (2018) who postulated teachers should experience hands-on interactive experience with the technology resources they are to use as well as how to use it with their existing curriculum.

Math teachers shared many concerns about relevance to the curriculum, indicating lower buy-in and greater hesitancy in embracing the STEM program. There was growth in teachers' self-efficacy in STEM after participating in the program. This agrees with Annetta et al. (2012) that effective STEM professional learning includes authentic use of the materials and methods. A few keys to successful STEM professional development were revealed, including a framework for priority emphasis on Time, Efficacy, and Equipment. This agrees with studies by Annetta et al. (2012), Bates and Morgan (2018), and Rosenzweig and Wigfield (2016) in that STEM professional development is unique and requires intentional focus to support teachers' growth in their STEM self-efficacy.

In Chapter III, there was no difference in students' average confidence and attitudes toward STEM compared across all seven middle schools in the district. This agrees with Hall (2015) that STEM learning is for and should be accessible to all; STEM is not just for certain types, learners, or demographics. Students had higher scores on their post-survey than their pre-survey, indicating positive growth in their attitudes toward STEM subjects and careers. Because teachers' self-efficacy in STEM also increased, this confirms a study by Sjaastad (2013) that teachers are particularly influential people to adolescents in regard to attitudes toward STEM.

In Chapter IV, races and genders of students were analyzed for differences in the students' levels of STEM confidence. There were no significant differences in confidence in and attitudes toward STEM by gender or race. Statistically, all races and both genders compared equally between categories. This agrees with studies by Brown et al. (2017), Perez-Felkner et al. (2012), and Boston and Cimpian (2018) that there is no gender inclination toward or against STEM occupations. Females showed growth in their confidence in and attitudes toward STEM, while minorities did not. The females' growth in confidence in and attitudes toward STEM agrees with Sjaastad's (2013) study on the significant influence teachers (in this district, female science and math teachers) have over adolescents. The lack of growth in minorities' STEM confidence agrees with studies by Grossman and Porche (2014), Leath and Chavous (2018), Morton and Parsons (2018), and Ridgeway and Yerrick (2018) that minority students can be discouraged from STEM learning when they lack minority STEM mentors.

Regarding the sustainability of the STEM program, the outcomes of higher STEM efficacy for teachers, and higher STEM confidence and attitudes for students after the program indicated the model of implementation was successful. This model can be replicated in the future with adjustments. However, although the model is effective, future STEM programs should involve different equipment for teacher and student use. Teacher feedback indicated that while the Spheros robots were helpful, the Lenovo tablets were not. The Little Bits and Cubelets were not as easily connected to the science and math curricula, and teachers struggled to incorporate them into their lessons. Additional research is needed on replicating this STEM program model with different equipment.

Theoretical Framework of Situated Learning Cognition

The theoretical framework for this study was that of situated learning cognition. The impact of situated learning cognition as a foundational philosophy for teaching and learning is evident throughout these studies. In Chapter II, the teachers' successes indicated by their comments and their growth in STEM self-efficacy as revealed by statistical analysis were the result of their learning by doing. In their workshop and classroom, they spent time learning by doing. Their work with the students in designing STEM lessons was their learning by doing and in turn fostering their students' learning by doing. In Chapter III, the students' confidence in and attitudes toward STEM grew, which may be the result of their participation in the program. In Chapter IV, the females' growth in their confidence and attitudes toward STEM subjects and careers may have been the result of their experiencing STEM, and likely because their STEM teachers were primarily female. With built-in female STEM role models learning and experimenting beside them, they were able to understand that girls can be scientists or mathematicians, too. The lack of minority teachers may have influenced the outcome of little to no growth in minority students' STEM confidence, because the minority students did not have the opportunity to learn from and experiment alongside STEM mentors reflecting their own race.

As the teachers looked toward the future of their STEM program, there were requests for more in-depth, hands-on training than there were for more equipment. The teachers appeared to value the learning experiences they had and requested more in order to increase their own STEM self-efficacy. Effective professional development, for all topics, but especially for STEM, should be designed with the framework of situated learning cognition in mind. Teachers may move into a transformed state of their instructional pedagogy when they have experienced real learning by doing. Situated learning cognition is the foundation for STEM. It can only be experienced through interactions, collaboration, and connection to the cross-curricular content. STEM is not a concept one can study theoretically, or be lectured on, and truly understand. STEM demands to be experienced, and when it is experienced, we see positive change in teachers and their students.

Implications of the Study

The implications of each study vary. In Chapter II, a more specific study required more or a more balanced set of responses between teachers and students. Regarding teacher differences in efficacy, this shows that each subject area needs one another to collaboratively design successful STEM endeavors for their students. The program was successful in part for the teachers, but the gains made were small. Further, more hands-on training is needed for these teachers to continue cultivating their self-efficacy in STEM. Professional development leaders should consider Time, Efficacy, and Equipment as three main focus areas of their STEM-focused workshops for teachers.

In Chapter III, the program was consistent across the district and mildly successful in bringing gains to students' confidence in and attitudes toward STEM. Most of the success seems to have come from technology teachers taking the lead on coding while science and math teachers used Spheros for most of their STEM lessons. Teachers' comments in their survey responses indicated that the Sphero was by far the most valuable asset in their STEM kits.

In Chapter IV, the positive effect of this STEM program could be seen, including the equipment and in consideration of the primarily female-nature of the science and math teachers. Female students' growth in their STEM confidence indicates a meaningful impact by their teachers, yet minorities were unaffected by the program. This may indicate that more females and minority teachers of STEM subjects are needed in classrooms and STEM leadership to positively influence minority and female students across the district. The lack of growth in minority students indicates a need for intentional focus on providing minority students in this school district with representation in their classrooms in science, math, and technology teachers but also in library books, guest speakers, STEM resource websites, books, posters, videos, and other media of STEM experts who are minorities. Minority students need to know that STEM is not just for White people. They need to know that their cultural perspective is needed to marshal STEM education and professions into the next age of modern history.

Recommendations for Future Research

Recommendations for further research begin with replicating this study using a more balanced data set. A balance of pre- and post-survey responses from students would provide a better statistical perspective of the program's outcomes. Matching and coding student responses from their pre- and post-surveys would provide an even clearer picture of the program's effectiveness. Replicating the program with different equipment might also be significant in advising professional development leaders in selecting resources for other schools and districts. A deeper analysis of teacher types, schools, and an interaction between those data points and student outcomes would be very interesting. A study of females by school and minorities by school could be useful for those studying gender and/or race and socioeconomic status. Interviews with minority and female students could help shed light on the relationship between the Critical Race Theory and their experiences with STEM learning. A closer look at the intersection of gender and race would be helpful to the growing field of literature about this topic. Finally, a longitudinal study on this cohort of students would be interesting in determining how this program may have impacted their high school course selections and post-graduation plans.

Conclusion

This study investigated the impact of a STEM program on adolescents in a southeastern public school district. Using surveys collected from students and teachers, results were analyzed in a number of ways to determine the program's effectiveness for different groups of affected individuals. The results indicated overall growth in students and teachers, providing context for designing and measuring successful STEM programs for adolescents and their teachers.

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APPENDIX A

IRB APPROVAL

THE UNIVERSITY OF ALABAMA | Office of the Vice President for Research & Economic Development
Office for Research Compliance

October 29, 2018

Michelle Wilson
Department of ELPTS
College of Education
The University of Alabama
Box 870302

Re: IRB # EX-18-CM-095: "Cultivating the Roots of STEM: Investigating the Impact of a Science, Technology, Engineering, and Math Program on Adolescents"

Dear Mrs. Wilson,

The University of Alabama Institutional Review Board has granted approval for your proposed research. Your application has been given exempt approval per 45 CFR part 46.101(b)(4) as outlined below:

(4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects.

This approval will expire on October 28, 2019. If the study continues beyond that date, please submit the Continuing Review Form within e-Protocol. If you modify the application, please submit the Amendment Form. Changes to this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants. When the study closes, please submit the Final Report Form.

Should you need to submit any further correspondence regarding this application, please include the assigned IRB approval number. Good luck with your research.

Sincerely,

[redacted]
Director & Research Compliance Officer
Office for Research Compliance

cc: Dr. Margaret Rice

358 Rose Administration Building | Box 870127 | Tuscaloosa, AL 35487-0127
205-348-8461 | Fax 205-348-7189 | Toll Free 1-877-820-3066

APPENDIX B

FRIDAY INSTITUTE TEACHER: TEACHER EFFICACY AND ATTITUDES TOWARD STEM (T-STEM) SURVEY

SCIENCE

Friday Institute for Educational Innovation. (2012). *Teacher Efficacy and Attitudes Toward STEM Survey-Science Teachers*. Raleigh, NC: Author.

The development of this survey was partially supported by the National Science Foundation under Grant No. 1038154 and by The Golden LEAF Foundation.

The framework for part of this survey was developed from the following sources: Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an elementary teachers science teaching efficacy belief instrument. *Science Education, 74*(6), 625-637. doi: 10.1002/sce.3730740605

This survey was modified with permission from the Friday Institute. The number of questions for teachers on the T-STEM was reduced from to 55 to 32 to protect participants from survey fatigue and to ensure the greatest number of completed questionnaires.

1. I am continually improving my technology teaching practice.
(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

2. I understand technology concepts well enough to be effective in teaching technology.
(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

3. I know what to do to increase student interest in technology.
(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

4. The teacher is generally responsible for students' learning in technology.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

5. Minimal student learning in technology can generally be attributed to their teachers.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

How often in your technology instruction do you…

6. Use a variety of technologies (productivity, data, visualization, research, and communication tools)

(Never, Occasionally, About half the time, Usually, Every time, Not Applicable)

7. Use technology to communicate and collaborate with others, beyond the classroom.

(Never, Occasionally, About half the time, Usually, Every time, Not Applicable)

8. Use technology to access online resources and information as a part of activities.

(Never, Occasionally, About half the time, Usually, Every time, Not Applicable)

9. Work on technology-enhanced projects that approach real-world applications of technology.

(Never, Occasionally, About half the time, Usually, Every time, Not Applicable)

10. Use technology to solve problems.

(Never, Occasionally, About half the time, Usually, Every time, Not Applicable)

11. Use technology to support higher order thinking (analysis, synthesis, and evaluation of ideas and information)

(Never, Occasionally, About half the time, Usually, Every time, Not Applicable)

12. Develop problem-solving skills through investigations (scientific, design, or theoretical investigations).

(Never, Occasionally, About half the time, Usually, Every time, Not Applicable)

During technology instruction, how often do your students…

13. Work in small groups.

(Never, Occasionally, About half the time, Usually, Every time, Not Applicable)

14. Make predictions that can be tested.

(Never, Occasionally, About half the time, Usually, Every time, Not Applicable)

15. Make careful observations or measurements.

(Never, Occasionally, About half the time, Usually, Every time, Not Applicable)

16. Create reasonable explanations of results of an experiment or investigation.

(Never, Occasionally, About half the time, Usually, Every time, Not Applicable)

17. Complete activities with a real-world context.

(Never, Occasionally, About half the time, Usually, Every time, Not Applicable)

18. Learn about careers related to technology.

(Never, Occasionally, About half the time, Usually, Every time, Not Applicable)

I think it is important that students have learning opportunities to…

19. Respect the differences of their peers.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

20. Help their peers.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

21. Make changes when things do not go as planned.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

22. Manage their time wisely when working on their own.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

23. Work well with students from different backgrounds.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

I think it is important that teachers…

24. Take responsibility for all students' learning.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

25. Establish a safe and orderly environment.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

26. Empower students.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

I know…

27. About current STEM careers.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

28. Where to go to learn more about STEM careers.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

29. Where to find resources for teaching students about STEM careers.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

30. Where to direct students or parents to find information about STEM careers.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

Open-Ended Questions Added by the District

31. In the past, what STEM or STEAM activities have you included in your instruction?

open-ended responses

32. What concerns or suggestions do you have regarding the implementation of the Middle School Grant?

open-ended responses

SCIENCE T-STEM SURVEY

Same surveys as above, replacing technology with science.

MATH T-STEM SURVEY

Same surveys as above, replacing technology with math.

APPENDIX C

FRIDAY INSTITUTE S-STEM SURVEY—MIDDLE AND HIGH SCHOOL STUDENTS

S-STEM SURVEY

Friday Institute for Educational Innovation. (2012). *Student Attitudes toward STEM Survey—Middle and High School Students*. Raleigh, NC: Author.

The development of this survey was partially supported by the National Science Foundation under Grant No. 1038154 and by The Golden LEAF Foundation.

The framework for part of this survey was developed from the following sources:

Erkut, S., & Marx, F. (2005). *4 schools for WIE (Evaluation Report)*. Wellesley, MA: Wellesley College, Center for Research on Women. Retrieved April 5, 2012 from http://www.coe.neu.edu/Groups/stemteams/evaluation.pdf

Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook, 2010-11 Edition*.

This survey was modified with permission from the Friday Institute. The district elected to reduce the total number of questions for students from 56 items to 25. The number of questions for teachers was reduced from to 55 to 32. The district's purpose in reducing the survey items was to protect participants from survey fatigue and to ensure the greatest number of completed questionnaires.

School

Race

Gender

1. I would consider a career that uses math.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

2. I can handle most subjects well, but I cannot do a good job with math.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

3. I can get good grades in math.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

4. I am good at math.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

5. I am sure of myself when I do science.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

6. I expect to use science when I get out of school.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

7. I know I can do well in science.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

8. I can handle most subjects well, but I cannot do a good job with science.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

9. If I learn engineering, then I can improve things people use every day.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

10. I am good at building and fixing things.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

11. I would like to use creativity and innovation in my future work.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

12. Knowing how to use math and science together will allow me to invent useful things.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

13. I am confident that I can respect the differences of my peers.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

14. I am confident I can help my peers.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

15. I am confident I can include others' perspective when making decisions.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

16. I am confident I can make changes when things do not go as planned.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

17. When I have many assignments, I can choose which ones need to be done first.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

18. I am confident I can work well with students of different backgrounds.

(Strongly Disagree, Disagree, Neither Disagree nor Agree, Agree, Strongly Agree)

19. Mathematics: is the science of numbers and their operations. It involves computation, algorithms, and theory used to solve problems and summarize data. (ex: accountant, applied mathematician, economist, financial analyst, statistician, market researcher, stock market analyst, etc.)

(Not at all interested, Not so interested, Interested, Very interested)

20. Medicine: involves maintaining health and preventing/treating disease. (ex: physician's assistant, nurse, doctor, nutritionist, emergency medical technician, physical therapist, dentist, etc.)

(Not at all interested, Not so interested, Interested, Very interested)

21. Earth Science: is the study of earth, including the air, land, and ocean. (ex: geologist, weather forecaster, archaeologist, etc.)
(Not at all interested, Not so interested, Interested, Very interested)

22. Computer Science: consists of the development and testing of computer systems, designing new programs, and helping others use computers. (ex: computer support specialist, computer programmer, computer and network technician, gaming designer, computer software engineer, information technology specialist, etc.)
(Not at all interested, Not so interested, Interested, Very interested)

23. Chemistry: uses math and experiments to search for new chemicals, and to study the structure of matter and how it behaves. (ex: chemical technician, chemist, chemical engineer, etc.)
(Not at all interested, Not so interested, Interested, Very interested)

24. Energy: involves the study and generation of power, such as heat or electricity. (ex: electrician, electrical engineer, heating, ventilation, air conditioning technician, etc.)
(Not at all interested, Not so interested, Interested, Very interested)

25. Engineering: involves designing, testing, and manufacturing new products like machines, bridges, buildings, and electronics through the use of math, science, and computers. (ex: civil, industrial, agricultural, or mechanical engineers, welder, auto-mechanic, construction manager,

etc.)

(Not at all interested, Not so interested, Interested, Very interested)

APPENDIX D

PERMISSION TO USE AND MODIFY INSTRUMENTS

Friday Institute S-STEM and T-STEM Surveys
8 messages

[redacted]@ncsu.edu> Mon, Jan 22, 2018 at 3:50 PM
[redacted]n@ncsu.edu>

[redacted]

The Science House
North Carolina State University
909 Capability Dr.
Raleigh, NC 27606
abalexan@ncsu.edu

From: [redacted]@ncsu.edu>
Date: Thursday, January 11, 2018 at 10:37 AM
Subject: Friday Institute S-STEM and T-STEM Surveys

Thank you for your interest in using our evaluation instruments. These evaluation instruments were identified, modified, or developed through support provided by the Friday Institute. The Friday Institute grants you permission to use these instruments for educational, non-commercial purposes only. You may use an instrument "as is", or modify it to suit your needs, but in either case you must credit its original source. By using this instrument you agree to allow the Friday Institute to use the de-identified data collected for additional validity and reliability analysis. You also agree to share with the Friday Institute publications, presentations, evaluation reports, etc. that include data collected and/or results from your use of these instruments. The Friday Institute will take appropriate measures to maintain the confidentiality of all data.

The STEM surveys (as pdfs) can be accessed and downloaded from here: [redacted]**.** Please feel free to contact me if you have any further questions or inquiries related to the S-STEM and T-STEM surveys. Thank you.

Instruments related to **technology innovation, professional development and workforce development** can be downloaded (as pdfs) here: [redacted]. This includes all 1:1 instruments and technology needs assessment.

Additionally, please see attached for the elementary, middle, and high school versions of our STEM Implementation Rubric. The elementary and middle school versions are identical, and there are some slight differences in the high school rubric. We hope you find this useful in your work and would be happy to hear of any thoughts you have on its usefulness, improvements, etc. We have recommended citations on the front page of each rubric as well.

Please use the recommended citation for the S-STEM and T-STEM surveys:

Friday Institute for Educational Innovation (2012). *Middle and High School STEM-Student Survey*. Raleigh, NC: Author.

Friday Institute for Educational Innovation (2012). *Elementary School STEM - Student Survey*. Raleigh, NC: Author.

Friday Institute for Educational Innovation (2012). *Teacher Efficacy and Attitudes Toward STEM Survey-Elementary Teachers*. Raleigh, NC: Author.

Friday Institute for Educational Innovation (2012). *Teacher Efficacy and Attitudes Toward STEM Survey-Science Teachers*. Raleigh, NC: Author.

Friday Institute for Educational Innovation (2012). *Teacher Efficacy and Attitudes Toward STEM Survey-Technology Teachers*. Raleigh, NC: Author.

Friday Institute for Educational Innovation (2012). *Teacher Efficacy and Attitudes Toward STEM Survey-Engineering Teachers*. Raleigh, NC: Author.

Friday Institute for Educational Innovation (2012). *Teacher Efficacy and Attitudes Toward STEM Survey-Mathematics Teachers*. Raleigh, NC: Author.

APPENDIX E

FOLLOW-UP TEACHER SURVEYS

1. Which school?
2. What subject?
3. How have you used the Cubelets?
4. How have you used the Sphero?
5. How have you used the Tablets?
6. How have you used the Little Bits?
7. What struggles have you experienced using this equipment?
8. What would make you more comfortable using this equipment?
9. What successes have you experienced in using this equipment?